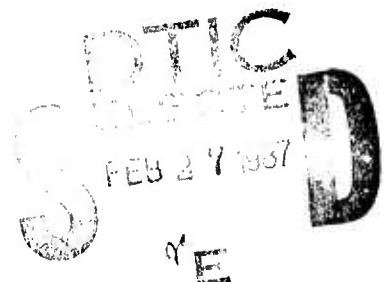


VOLUME 18, NO. 12
DECEMBER 1986

(1)

THE SHOCK AND VIBRATION DIGEST

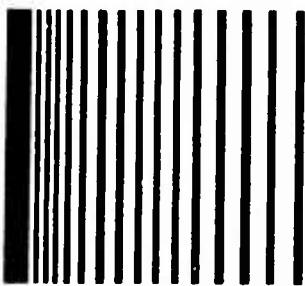
A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.



OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING

Approved for public release; distribution unlimited.

87 2 25 128



THE SHOCK AND VIBRATION DIGEST

Volume 18, No. 12
December 1986

STAFF

Shock and Vibration Information Center

EDITORIAL ADVISOR: Dr. J. Gordan Showalter

Vibration Institute

EDITOR:	Judith Nagle-Eshleman
TECHNICAL EDITOR:	Ronald L. Eshleman
RESEARCH EDITOR:	Milda Z. Tamulionis
COPY EDITOR:	Loretta G. Twohig
PRODUCTION:	Barbara K. Solt
	Betty J. Schalk

BOARD OF EDITORS

R.L. Bort	W.D. Pilkey
J.D.C. Crisp	H.C. Pusey
D.J. Johns	E. Sevin
B.N. Leis	R.A. Skop
K.E. McKee	R.H. Volin
C.T. Morrow	H.E. von Gierke



A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research
Laboratory
Washington, D.C. 20375-5000
(202) 767-2220

Dr. J. Gordan Showalter
Acting Director

Rudolph H. Volin

Elizabeth A. McLaughlin

Mary K. Gobbett

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206, 101 West 55th Street
Clarendon Hills, Illinois 60514
(312) 654-2254

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$200.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available -- Volumes 11 through 16 -- for \$40.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, D.C. 20375-5000. The Secretary of the Navy has determined that this publication is necessary in the transaction of business required by law of the Department of the Navy. Funds for printing of this publication have been approved by the Navy Publications and Printing Policy Committee.

EDITOR'S RATTLE SPACE

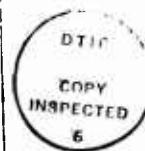
FAREWELL TO A FRIEND

It is now common knowledge that the Shock and Vibration Center (SVIC) was officially disestablished on 1 October 1986 after forty years of service to the shock and vibration community. This service included the organization of Shock and Vibration Symposia and the publication of the Shock and Vibration Bulletin, the Shock and Vibration Digest, and a monograph series. SVIC acted as a repository and clearing house for technical information on vibration and shock associated with a wide variety of equipment and environments. It is unfortunate that an important group of this type was disestablished when the exchange of technical information is so important to save time, resources, and money. While some of these services will be continued, given the present economic conditions, it is unlikely that a single focal point of the nature of the SVIC can be established again -- particularly within the government.

The Vibration Institute will continue the publication of the Shock and Vibration Digest in the same form without interruption. Since the Institute has prepared the DIGEST for SVIC for the past eleven years, similar service can be continued with ease. The continuation of the other functions present more of a challenge. Meetings at the recent 57th Shock and Vibration Symposium indicate that many persons are very interested in the continuation of the services provided by SVIC. As a result, efforts are now underway to find a means of continuation of some or all of SVIC's services. Unfortunately while some or many of these services may be reinstated, the tradition and focal point of SVIC will be lost.

From a personal view, it is with regret that I say farewell to a friend -- SVIC. As the technical editor of the DIGEST, I have been closely associated with the SVIC for the past eighteen years. The DIGEST offered me a rare opportunity to grow in the technical world. I wish to thank the SVIC personnel present and past for their cooperation, sponsorship, contributions. It was always a pleasant task working with the SVIC personnel -- four of the five directors: Drs. Mutch and Belsheim, Henry Pusey, and Gordan Showalter; Rudy Volin who served on the SVIC staff during my entire tenure on the DIGEST; and Elizabeth McLaughlin who maintained the office. While my activity with the DIGEST will continue, the association with the SVIC personnel will be missed.

Accession No.		R.L.E.
NTIS 74A1		X
DSC 100		
100-10000		
NR L		40.00
per copy		
A-1		21



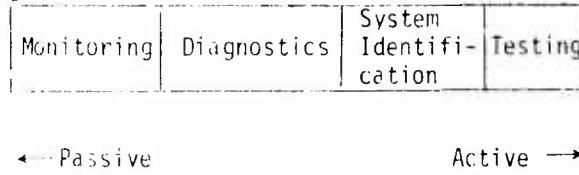
MECHANICAL SIGNATURE ANALYSIS

M.S. Hundal*

Abstract. Literature on mechanical signature analysis (MSA) for 1983-85 is reviewed. MSA applications discussed include analytical and experimental methods, programs, and systems for machinery and process monitoring and diagnosis.

A previous article [40] that reviewed literature on mechanical signal analysis (MSA) up to the end of 1982 included analytical and experimental studies, monitoring, and diagnostics of machines. Since that time the use of sophisticated instrumentation and systems for data acquisition and processing has become well established, and new analytical techniques have been developed.

MSA includes a number of applications [8]: 1) monitoring, 2) diagnostics, 3) system identification, and 4) testing. These can further be classified into active and passive insofar as the external stimuli applied to the system by the user (see the figure). The aims of MSA include improved system design, noise and vibration attenuation, and help in developing control strategies.



MSA Applications.

Because the published literature on MSA is so extensive, only applications to monitoring and diagnostics are covered in this paper. This literature is divided into the following groups: general monitoring and diagnostics; monitoring and diagnostic systems; specific machine elements; analytical techniques; sound, ultrasound, and acoustic emission applications; and special applications and techniques.

GENERAL MONITORING AND DIAGNOSTICS

For the novice in MSA several papers provide a good introduction to the subject. Eshleman [25]

and Mitchell [72] discuss diagnostic capabilities of FFT analyzers. Other papers contain evaluations of data, location and types of measurements [77], high-frequency bearing monitoring [35], current trends in diagnosis and economics of monitoring [87], and different types of spectra used for diagnostics [55]. Mitchell [70] examines issues in establishing a monitoring program and provides a survey of methods.

Eshleman [26] and Buehler [10] give examples of typical vibration signals and spectra associated with different types of machinery faults. Cost-effective predictive maintenance of noncritical rotating equipment [58], factors other than machine deterioration that cause changes in vibration signature [16], and engine torque and speed for condition monitoring [46] have been presented. Fox [29] and Fuchs [31] discuss measurement of absolute and relative motion and effect of mass of system components.

Effects of misalignment in couplings and its causes and identification have been presented [23,52,80]. Ghosh [33] has presented effects of balancing, generator excitation, loading, and rebuilding on hydraulic turbine vibration signatures. The problems of identifying and diagnosing problems in vertical pumps [89], steam turbine fan system [73], freight car bearings [48], electric motors [11,12,34], and rotary blowers [44] have been discussed. Eshleman and Jones [27] have presented the use of test data and a computer model to reduce vibration in a turbine with thermal bow. A monitoring system for gas turbine cases has been given by Kidd [47].

MONITORING AND DIAGNOSTIC SYSTEMS

The developments in instrumentation for measurement and analysis of mechanical signals have led to research in and design of complete systems for monitoring and diagnosis. Papers in this area describe design aspects, operating experience, and philosophy behind such systems [7]; systems for improving machine availability and reducing maintenance costs [5,71]; a program to schedule monitoring activities [83]; and a

* Department of Mechanical Engineering, University of Vermont, Burlington, Vermont 05405

diagnostic system containing spectrum, balance, and predictive maintenance analyzers [67].

Remote monitoring and control systems have been discussed for gas turbines [28,32] and offshore gas turbine fatigue life prediction [98]. Such systems have been applied to a diesel engine to infer behavior of pressure and forces from vibration signal [57], to self-aligning thrust bearings in steam turbines [100], and to piping systems to determine maximum stress [84]. A portable system for data acquisition, analysis, and early diagnosis for power plants [13] and diagnostic functions of a turbomachinery system [2] have been presented.

Research projects on torsional fatigue life and development of statistics for making conclusions and recommendations on system operations have been described [103]. Systems with satellite stations at each component, communication networks, and required computer hardware and software have been presented [19,38].

Application of expert systems for monitoring and providing data for use by management has been discussed [90,91]. A system to maintain data records, compute statistical data, and prepare reports for management [20] as well as software for using stored diagnostic files for fault diagnosis as part of an expert system [14] have been described.

MACHINE ELEMENTS

Bearings. Bearings are by far the most common elements monitored for machinery condition. Although most papers deal with rolling element bearings, a paper by Conway-Jones [18] discusses the measurement of oil-film pressure and journal displacement for monitoring engines.

Methods to locate defects in ball bearings with single or multiple dents have been presented by Igarashi [42,43]. Effects on vibration signals generated by defects in raceways, rolling elements, excessive clearance, and lack of lubrication have been discussed [3]. In a series of reports McFadden and Smith [61,62,64-66] have described models, experimental methods, and high-frequency resonance techniques used to detect single and multiple defects in rolling element bearings. A study to detect incipient failure has been presented [60]; links among metallography, tribology, noise, and vibration analysis [102] have been explored. Use of eddy current sensors for bearing monitoring has been discussed [37,88].

Gears. General papers on monitoring gearbox vibrations deal with fault identification [4,93]. Milenkovic [69] has discussed a methodology for measuring vibrations in axle carriers outside a vehicle. A method for predicting tooth surface failure [101] and detecting shaft misalignment, eccentricity, and profile errors from noise and vibration signatures [50] has been presented. Jacobs [45] has given a case history of a monitoring program that failed to detect a major fault in a gear reducer.

ANALYTICAL TECHNIQUES

A number of papers describe new analytical techniques or the application of existing techniques to new applications in MSA. The random decrement method has been used by Yang [106, 107] to inspect offshore structures. Ranking of noise sources and disturbances has been discussed [9,99]. Tanaka [94] gives classification factors for detectability of blade vibrations. A method for finding parameters of a multi-frequency signal [36] and synthesis of periodic signals to provide improved spectral response data [79] have been presented.

Powell [78] has described a method capable of separating multiple input force signals in the presence of reverberated signals; the method involves constructing a pseudo-inverse transfer matrix. Signal recovery in reverberent structures to reveal developing faults has been given by Lyon [56]. Pavic [75,76] has developed relationships between inertial and elastic properties to detect vibrations by strain measurements. A method for tracking the progress of fracture by observing changes in mass, stiffness, and damping matrices has been discussed [108]. Cempel [17] has described a model that combines wear, vibration, and acoustic processes to predict machine condition and estimate breakdown time.

Algorithms for fault identification from vibration signatures by a method of elimination [51] and time dependent processing to enhance dynamic test data [95] have been presented. Use of redundant measurement systems with adaptive filtering, use of fault detection, and isolation methodology have been described by Ray [82]. Davies [21] has discussed three parametric methods -- prony series, recursive least squares, and instrumental variable analysis -- and compared them with Fourier methods. A frequency domain technique for fault diagnosis and computer language that reduces software cost and complexity have been given by Hitchcock [39]. Real time programs that can indicate a 0.1 percent change in rotor unbalance are available [86]. A method for simulating an impulsive

fault signal buried in background noise and modeling various stages of incipient failure have been given by White [104].

SOUND, ULTRASOUND, AND ACOUSTIC EMISSION SIGNALS

Although most MSA applications involve monitoring only vibration signals, in some cases both sound and vibration signals are used for diagnostics [42,43,101]. Hundal [41] has described the use of acoustic and vibration signatures of a power plant ash conveyor to solve a community noise problem. A sound intensity measuring technique for machinery diagnostics [81] and ultrasonic signals for detecting rolling bearing defects [15] have been presented. Armor [1] has given a progress report of on-line detection of shaft cracks using vibration signature analysis, acoustic emission (AE), and eddy current sensor monitoring.

The AE technique has been used in the past mainly to detect faults in structures. It is being used in machine monitoring. AE applications for rolling bearing monitoring at low speeds [63] and for diagnosis of friction change in mating slides [92] have been given. Yoshioka [110] has described the principle of an AE source-locating system for rolling bearings. Manufacturing applications of AE have been presented in the context of grinding [24] and wood cutting [54]. More traditional applications of AE technique have also been discussed: internally leaking parallel piping in spacecraft [105], operational monitor for a towed cable system [53], and glass reinforced composites [6].

SPECIAL APPLICATIONS AND TECHNIQUES

Some applications and techniques in MSA do not fall under any of the previous categories. An instrument to detect looseness of a screw in a gearbox assembly [49] and vibration monitoring of high-volume transfer machines in an automotive engine plant [97] have been presented. Timperley [96] has presented a method for incipient failure detection in rotating machines with EMI monitoring. Use of burst random excitation to eliminate leakage errors and distortion of frequency response [74] and the use of a Laser doppler sensor for turbine generator vibrations [59] have been described.

Freestone [30] used Fourier analysis of a crank-shaft waveform as a diagnostic tool to estimate the power contribution of each cylinder of an engine. Use of pattern recognition techniques to distinguish waveforms from damage-related and extraneous sources has been discussed [85].

Monitoring a machine tool with strain gauges [68]; investigation of lubricant action in cutting [22]; and a system for predicting imminent failure of workpiece, tool, or worn tool [109] have been described for manufacturing applications.

CONCLUSIONS

In the past three years the field of MSA has matured significantly. This is evidenced not only by the large number of published articles on monitoring and diagnostics, but also by literature in analytical and experimental modal analysis. In addition, new journals devoted exclusively to modal and signal analysis are now being published. In the last review of MSA [40] a number of areas of future work were postulated. It is satisfying to note that most of these areas have seen significant activity. At this time it appears that the following topics will be important in the next few years:

- Combination of modal analysis with monitoring and diagnostics systems
- Identification of measures of system degradations and prediction of failure
- Time domain analysis as aid in diagnostics and failure prediction
- Combination of techniques; e.g. vibration, sound, ultrasound, and AE in diagnostic systems
- Expert systems and AI

REFERENCES

1. Armor, A.F., "On-Line Monitoring of Turbine-Generator Shaft Cracking," ASME Paper No. 83-JPGC-Pwt-7 (1983).
2. Arnold, W.L., "Expand Supervisory Function to Include Diagnostics," Power, 122 (12), pp 61-63 (Dec 1983).
3. Axton, G.E. "Antifriction Bearing Pre-Failure Detection Makes Dollars and 'Sense,'" Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 105-113, (June 26-28, 1984).
4. Bagiassa, K., Suganda, H., and Suharto D., "Noise Analysis for Gear Box Defect Detection," SAE Paper No. 830924 (P-139) (1983).
5. Bannister, R.L., Bellows, J.C., and Osborne, R.L., "Steam Turbine Generators - On-line Monitoring and Availability," Mech. Engrg., 105 (7), pp 55-59 (July 1983).

6. Belchamber, R.M., Betteridge, D., Collins, M.P., and Lilley, T., "Time Series Analysis of Acoustic Emission Signals from Glass Reinforced Plastics," *Acoust. Emission Monitoring Anal.* Mfg., ASME, New Orleans, LA, pp 1-9 (1984).
7. Boyce, M.P., Meher-Homji, C., Mani, G., Lam, T., and Ansell, R., "Operating Experience with Health Monitoring and Diagnosis of M.D. Steam Turbines and Centrifugal Compressors," ASME Paper No. 83-JPGC-Pwr-28 (1983).
8. Braun, S., "MSA - Mechanical Signature Analysis," *J. Vib., Acoust., Stress, Rel. Des., Trans. ASME*, **106** (1), pp 1-3 (Jan 1984).
9. Braun, S. and Shulman, D., "The Use of Signal Analysis and Identification Methods for Correction of Unbalance Computations," *J. Vib., Acoust., Stress, Rel. Des., Trans. ASME*, **106** (1), pp 53-58 (Jan 1984).
10. Buehler, M.W. and Bertin, C.D., "Typical Vibration Signatures - Case Studies," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 191-206 (Apr 19-21, 1983).
11. Campbell, W.R., "Shaft Runout Under Eddy Current Non-contact Probes," Proc., Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 39-51 (Apr 19-21, 1983).
12. Campbell, W.R., "Diagnosing Alternating Current Electric Motor Problems," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 65-79 (May 22-24, 1985).
13. Canada, R.G., Greene, R.H., and Craig, P.J., "A State-of-the-Art Monitoring and Diagnostic Program for Main Steam Turbines in Commercial Power Plants," Proc. Mach. Vib. Monitoring Analysis Mtg., Houston, TX, Vibration Institute, pp 207-213 (Apr 19-21, 1983).
14. Carey, J.H., "The Use of Software for Vibration Monitoring," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 129-134 (May 22-24, 1985).
15. Catlin, J.B., "The Use of Ultrasonic Diagnostic Techniques to Detect Rolling Element Bearing Defects," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 123-130 (Apr 19-21, 1983).
16. Catlin, J.B., "A Survey of Factors Which Affect the Measured Vibration Spectra of Machines," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 51-56 (May 22-24, 1985).
17. Cempel, Cz., "The Triboviscoacoustical Model of Machines," *Wear*, **105** (3), pp 297-305 (Oct 1, 1985).
18. Conway-Jones, J.M., Jones, G., and Kendrick, M., "Crankshaft Bearings: Advances in Predictive Techniques and Measurements in Engines," ASME Paper No. 84-DGP-4 (1984).
19. Cook, S.A., Crowe, R.D., Roblyer, S.P., and Toffer, H., "Vibration Monitoring of Large Vertical Pumps Via a Remote Satellite Station," Vib. Sound Conf., ASME, Cincinnati, OH (Sept 10, 1985).
20. Corley, J.E., "A Vibration Monitoring Program Using Microcomputers," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 61-69 (June 26-28, 1984).
21. Davies, P. and Hammond, J.K., "A Comparison of Fourier and Parametric Methods for Structural System Identification," *J. Vib., Acoust., Stress, Rel. Des., Trans. ASME*, **106** (1), pp 40-48 (Jan 1984).
22. DeChiffre, L., "Frequency Analysis of Surfaces Machined Using Different Lubricants," *Trans. ASLE*, **22** (3), pp 220-226 (July 1984).
23. Dewell, D.L., and Mitchell, L.D., "Detection of a Misaligned Disk Coupling Using Spectrum Analysis," *J. Vib., Acoust., Stress, Rel. Des., Trans. ASME*, **106** (1), pp 9-16 (Jan 1984).
24. Dornfield, D. and He Gao Kai, "An Investigation of Grinding Wheel Loading Using Acoustic Emission," *J. Engrg., Indus., Trans. ASME*, **106** (1), pp 28-33 (Feb 1984).
25. Eshleman, R.L., "Machinery Diagnostics and Your FFT," *S/V Sound Vib.*, **12** (4), pp 12-18 (Apr 1983).
26. Eshleman, R.L., "Machinery Vibration Monitoring and Analysis - A Maintenance Tool," Proc. Intl. Coil Winding Assn., pp 76-80 (Oct 3-6, 1983).
27. Eshleman, R.L. and Jones, D., "Vibration Analysis and Balancing of a 192 MW Turbine Generator," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 87-94 (June 26-28, 1984).
28. Fanuele, F. and Rio, R.A., "Automated Diagnostic System for Engine Maintenance," ASME Paper No. 83-GT-103.

29. Fox, R.L., "Comparative Phase Measurements Aid Vibration Analysis," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 117-122 (Apr 19-21, 1983).

30. Freestone, J.W. and Jenkins, E.G., "The Diagnosis of Cylinder Power Faults in Diesel Engines by Flywheel Speed Measurement," Vehicle Condition Monitoring Fault Diag., I.Mech.E. Conf. Public. 1985-2, pp 15-24 (1985).

31. Fuchs, H.P., "Prevention of Vibration Damage by Maintenance," *Unstandshaltung Schwingschaeden vermeiden*, Industrie Anzeiger, 105 (79), pp 30-32 (Oct 5, 1983).

32. Geer, D.H., Johnson, D., and Pilcher, J.A., "A Modern Condition Monitoring and Gas Turbine Control System," ASME Paper No. 84-GT-220 (1984).

33. Ghosh, M. and Reddy, A.K., "Study of Vibration Behaviour of a Hydraulic Turbine," Proc. 5th Soc. Exptl. Stress Anal. Conf., pp 412-416 (June 1984).

34. Glew, C.A.W. and Reinhardt, W.A., "The Development of Vibration and Rundown Time Norms as a Quality Control Tool for Overhauled Electric Motors," Proc., 8th Canada Mach. Dynam. Sem., Halifax, Natl. Res. Council Canada, NRC No. 23619, pp 18.1-18.21 (Oct 1-2, 1984).

35. Goldman, S., "Periodic Machinery Monitoring: Do It Right," Hydrocarbon Processing, 63 (8), pp 51-56 (Aug 1984).

36. Grandke, T., "Interpolation Algorithms for Discrete Fourier Transforms of Weighted Signals," IEEE Trans., Instrum. Meas., IM-32 (2), pp 350-355 (June 1983).

37. Hansen, J.S. and Harker, R.G., "A New Method for Rolling Element Bearing Monitoring in the Petrochemical Industry," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 139-145 (June 26-28, 1984).

38. Harrington, T.P., Roblyer, S.P., and Toffer, H., "Vibration Monitoring Using a Computer Network Approach," ASME Paper No. 83-DET-72 (1983).

39. Hitchcock, K.N., "Recent Development in the Non-intrusive Diagnosis of Engine Faults," Vehicle Condition Monitoring Fault Diag., I.Mech.E. Conf. Public. 1985-2, pp 101-108 (1985).

40. Hundal, M.S., "Mechanical Signature Analysis," Shock Vib. Dig., 15 (6), pp 19-26 (June 1983).

41. Hundal, M.S., "Narrow-band Spectral and Propagation Analysis as Aids to Noise Source Identification," INTER-NOISE 85, Proc. Intl. Conf. Noise Control Engrg., Munich, pp 1335-1338 (Sept 18-20, 1985).

42. Igarashi, T. and Yabe, S., "Studies on the Vibration and Sound of Defective Rolling Bearings; Second Report: Sound of Ball Bearings with One Defect," Bull. JSME, 26 (220), pp 1791-1798 (Oct 1983).

43. Igarashi, T. and Kato, J., "Studies on the Vibration and Sound of Defective Rolling Bearings; Third Report: Vibration of Ball Bearings with Multiple Defects," Bull. JSME, 28 (237), pp 492-499 (Mar 1985).

44. Jacobs, R.W., "Detection of Mechanical Faults in Rotary Blowers," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 31-37 (Apr 19-21, 1983).

45. Jacobs, R.W., "Gear Reducers - Overall Readings are Not Enough!" Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 81-86 (May 22-24, 1985).

46. Jewitt, T.H.B. and Lawton, B., "The Use of Speed Sensing for Monitoring the Condition of Military Vehicle Engines," Vehicle Condition Monitoring Fault Diag., I.Mech.E. Conf. Public. 1985-2, pp 67-74 (1985).

47. Kidd, H.A., "Development of a Cast Vibration Measurement System for the DC-990 Gas Turbine," J. Engrg. Gas Turbines Power, Trans. ASME, 106 (4), pp 935-939 (Oct 1984).

48. Kim, P.Y. and Lowe, I.R.G., "A Review of Rolling Element Bearing Health Monitoring," Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 145-154 (Apr 19-21, 1983).

49. Kolitsch, J., "A Noncontacting Measurement Technique for a Continuous Monitoring of Screw Connections," (Ein beruehrungloses Messverfahren zur kontinuierlichen Ueberwachung von Schraubenverbindungen). VDIZ, 125 (3), pp 61-66 (Feb 1983).

50. Krishnappa, G., "Noise and Vibration Measurements of 50 kW Vertical Axis Wind Turbine Gear Box," Noise Control Engrg., J., 22 (1), pp 18-24 (Jan/Feb 1984).

51. Kubiak, J.A., Rothhirsch, L., and Aguirre, R., "An Algorithm of Fault Diagnosis for Turbine Generator Operations," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 91-100 (Apr 19-21, 1983).

52. Kubiak, J.A. and Aguirre, J.R., "Identification of Misalignment in Turbomachinery," Proc. Mach. Vib. Monitoring Anal. Mtg., New Orleans, LA, Vibration Institute, pp 23-30 (May 22-24, 1985).

53. Laura, P.A.A. and Matthews, J.R., "Monitoring the Status of a Mechanical Cable While in Operation by Means of the Acoustical Emission Method," Ocean Engrg., 12 (3), pp 211-219 (1985).

54. LeMaster, R.L., Tee, L.B., and Dornfeld, D.A., "Monitoring Tool Wear during Wood Machining with Acoustic Emission," Wear, 101 (3), pp 273-282 (Feb 1, 1985).

55. Leon, R.L., "Is Your Periodic Machinery Monitoring Program Telling You the Truth, the Whole Truth, and Nothing But ...?", S/V Sound Vib., 19 (6), pp 24-26 (June 1985).

56. Lyon, R.H., "Source Signature Recovery in Reverberant Structures," Shock Vib. Bull., Naval Res. Lab., Proc. 53, Pt. 4, pp 141-144 (May 1983).

57. Lyon, R.H. and DeJong, R.G., "Design of a High-Level Diagnostic System," J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (1), pp 17-21 (Jan 1984).

58. Makansi, J., "New Monitors Expand Benefits of Machine Condition Surveys," Power, 128 (5), pp 75-76 (May 1984).

59. Mannava, S.R., Mielke, W.R., and Armor, A.F., "A Noncontacting Laser Doppler Sensor for Monitoring Turbine Generator Vibrations," ASME Paper No. 83-JPGC-Pwr-26 (1983).

60. Mathew, J. and Alfredson, R.J., "The Condition Monitoring of Rolling Element Bearings Using Vibration Analysis," J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (3), pp 447-453 (July 1984).

61. McFadden, P.D. and Smith, J.D., "Vibration Produced by a Single Point Defect on the Inner Race of a Rolling Element Bearing Under Radial Load," Dept. Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-32-1983, PB84-139617 (1983).

62. McFadden, P.D. and Smith, J.D., "Implementing the High-Frequency Resonance Technique for the Vibration Monitoring of Rolling Element Bearings," Dept. Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-31-1983, PB84-14003 (1983).

63. McFadden, P.D. and Smith, J.D., "Acoustic Emission Transducers for Vibration Monitoring of Bearings at Low Speed," Dept. Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-29-1983, PB84-139526 (1983).

64. McFadden, P.D. and Smith, J.D., "Vibration Monitoring of Rolling Element Bearings by the High-Frequency Resonance Technique: A Review," Dept. Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-30-1983, PB84-139591 (1983); also Trib. Intl., 17 (1), pp 3-10 (Feb 1984).

65. McFadden, P.D. and Smith, J.D., "Vibration Produced by a Single Point Defect on the Inner or Outer Race of Rolling Elements of a Bearing under Radial or Axial Load," Dept. Engrg., Cambridge Univ., UK, Rept. No. CUED/C-MECH/TR-34-1983, PB84-169887 (1983).

66. McFadden, P.D. and Smith, J.D., "The Vibration Produced by Multiple Point Defects in a Rolling Element Bearing," J. Sound Vib., 98 (2), pp 263-273 (Jan 22, 1985).

67. McGuckin, W.J. and Schramm, E.J., "Diagnostic Analysis of Machinery with State-of-the-Art Equipment," S/V Sound Vib., 19 (6), pp 6-10 (June 1985).

68. Menz, P. and Heinke, H., "Signal Extraction for Automatic Monitoring of Machine Tool Drives," (Signalgewinnung zur automatischen Ueberwachung von Werkzeugmaschinenantrieben), Maschinenbautechnik, 32 (12), pp 544-547 (1984).

69. Milenkovic, V., Shmutter, S., and Field, N., "On-Line Diagnostics of Rear Axle Transmission Errors," J. Engrg. Indus., Trans. ASME, 106 (4), pp 331-338 (Nov 1984).

70. Mitchell, J.S., "How to Develop a Machinery Monitoring Program," S/V Sound Vib., 18 (2), pp 14-20 (Feb 1984).

71. Miell, J.S., "Efficient Machinery Screening for Improved On-Line Performance," S/V Sound Vib., 18 (9), pp 16-25 (Sept 1984).

72. Mitchell, L.D., "Signal Processing and the Fast Fourier Transform (FFT) Analyzer," Exptl. Tech., 2 (10), pp 3s-15s (Oct 1985).

73. Nathoo, N.S. and Crenwelge, O.E., "Case History of a Steam Turbine Rotordynamic Problem: Theoretical versus Experimental Results," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 81-89 (Apr 19-21, 1983).

74. Olsen, N., "Burst Random Excitation," S/V Sound Vib., 12 (11), pp 20-23 (Nov 1983).

75. Pavic, G., "Measurement of Vibration by Strain Gauges; Part I: Theoretical Basis," J. Sound Vib., 102 (2), pp 153-163 (Sept 22, 1985).

76. Pavic, G., "Measurement of Vibrations by Strain Gauges; Part II: Selection of Measurement Parameters," J. Sound Vib., 102 (2), pp 165-188 (Sept 22, 1985).

77. Peters, G., "Machinery Vibration Measurement and Monitoring," (Schwingungs-Messung und -Ueberwachung an Maschinen), Industrie Anzeiger, 105 (1/2) pp 32-33 (1983).

78. Powell, R.E. and Seering, W., "Multichannel Structural Inverse Filtering," J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (1), pp 22-28 (Jan 1984).

79. Pumplin, J., "Low-Noise Noise," J. Acoust. Soc. Amer., 28 (1), pp 100-104 (July 1985).

80. Quigley, W.J., "Fault Diagnosis Method for a Vibration Phenomenon on an Exciter for a Turbo-Alternator, through a Vibration Analysis Discrete Instant Motion Study Using Accelerometers and a Supporting Instrumentation System," Proc., 8th Canada Mach. Dynam. Sem., Halifax, Natl. Res. Council Canada, NRC No. 23619, pp 9.0-9.18 (Oct 1-2, 1984).

81. Rasmussen, G., "Application of Intensity Measuring Technique to Vibration Diagnostics in Machinery," Proc., 8th Canada Mach. Dynam. Sem., Halifax, Natl. Res. Council Canada, NRC No. 23619, pp 14.1-14.10 (Oct 1-2, 1984).

82. Ray, A. and Desai, M., "A Calibration and Estimation Filter for Multiply Redundant Measurement Systems," J. Dynam. Syst. Meas. Control, Trans. ASME, 106 (2), pp 149-156 (June 1984).

83. Remillard, R.L., "Data Management System for Predictive Maintenance Programs," S/V Sound Vib., 12 (9), pp 20-24 (Sept 1985).

84. Sampson, R.C., "Remote Sensing of Pipe Vibration," Exptl. Mech., Proc. 1985 SEM Spring Conf., Las Vegas, NV, pp 329-336 (June 9-14, 1985).

85. Scala, C.M. and Coyle, R.A., "Pattern Recognition and Acoustic Emission," NDT Intl., 16 (6), pp 339-343 (Dec 1983).

86. Schnittger, J.R., "Monitoring Mechanical Vibration using a Histogram Recorder," Intl. J. Fatigue, 2 (3), pp 145-153 (July 1983).

87. Smiley, R.G., "Rotating Machinery: Monitoring and Fault Diagnosis," S/V Sound Vib., 15 (9), pp 26-28 (Sept 1983).

88. Spencer D.E. and Hansen, J.S., "A Better Way to Monitor Bearings," Hydrocarbon Processing, 64 (1), pp 75-76 (Jan 1985).

89. Starr, D.E., "Troubleshooting Vertical Pumps Utilizing Vibration Techniques," Proc. Mach. Vib. Monitoring Anal. Mtg., Houston, TX, Vibration Institute, pp 131-133 (Apr 19-21 (1983).

90. Steward, R.M., "The Way Ahead for Machinery Health Monitoring as a Subset of Plant Control," Noise Vib. Control, 16 (2), pp 53-56 (Feb 1985).

91. Steward, R.M., "A Systematic Approach to Automated Machinery Management," S/V Sound Vib., 12 (6), pp 14-23 (June 1985).

92. Sturm, A. and Uhlemann, S., "Diagnostic Analysis of Slide Matings by Means of Sound Emission," (Diagnosik an Gleitpaarungen durch Schallemissionsanalyse), Maschinenbautechnik, 34 (3), pp 129-132 (1985).

93. Szrom, D.B., "Analysis and Correction of Gearbox Faults," Proc. Mach. Vib. Monitoring and Analysis Mtg., New Orleans, LA, Vibration Institute, pp 147-153 (June 26-28, 1984).

94. Tanaka, S., Hayashida, M., Umemura, S., and Katayama, K., "Monitoring of Blade Vibration through Detecting of Bearing Pedestal Vibration," ASME Paper No. 83-JPGC-Pwr-10 (1983).

95. Taylor, J.S.W., "Digital Techniques for Enhancing and Processing Dynamic Stress Analysis Data," Exptl. Tech., 2 (6), pp 31-35 (June 1983).

96. Timperley, J.E., "Incipient Fault Identification through Neutral RF Monitoring of Larger Rotating Machines," IEEE, Trans., Power Appl. Syst., PAS-102 (3), pp 693-698 (Mar 1983).

97. Tjong, J.S.-Y., Moore, T., and Reif, Z., "Application of Vibration Monitoring to High Volume, Multi-station Transfer Machines," *Intl. Modal Anal. Conf.*, Orlando, FL, Vol. II, pp 915-919 (Jan 28-31, 1985).

98. Toler, D.F. and Yorio, R.M., "Operational Mode Monitoring of Gas Turbines in an Offshore Gas-Gathering Application," *J. Engrg. Gas Turbine Power, Trans. ASME*, 106 (4), pp 940-945 (Oct 1984).

99. Tretthewey, M.W., Evenson, H.A., and Shapton, W.R., "Combination of Multiple Input Models and Experimental Modal Analysis for Identification of Structural Noise Generating Mechanisms: With Application to Forge Hammers," *Noise Control Engrg. J.*, 21 (3), pp 89-102 (Nov/Dec 1983).

100. Tuncel, O., Carter, D.B., and Sert, B., "Remote Monitoring of Steam Turbine Parameters of the New Self-aligning Thrust Bearing," *ASME Paper No. 83-JPGC-Pwr-13* (1983).

101. Umezawa, K., Ajima, T., and Houjoh, H., "An Acoustic Method to Predict Tooth Surface Failure of Inservice Gears," *NDT Intl.*, 16 (4), pp 201-204 (Aug 1983).

102. Volker, E. and Martin, H.R., "Early Detection of Damage in Rolling Bearings," *ISA Trans.*, 23 (3), pp 27-32 (1984).

103. White, J.C., Walker, D.N., and Perez, A.J., "Torsional Monitoring of Large Steam Turbine Generators," *ASME Paper No. 83-JPGC-Pwr-2* (1983).

104. White, M.F., "Simulation and Analysis of Machinery Fault Signals," *J. Sound Vib.*, 93 (1), pp 95-116 (Mar 8, 1984).

105. Wichmann, H. and Phillips, D., "Acoustic Emission Techniques for Locating Internal Leakage of Redundant Components," *J. Spacecraft Rockets*, 21 (1), pp 36-40 (Jan/Feb 1984).

106. Yang, J.C.S., Dagalakis, N.G., Everstine, G.C., and Wang, Y.F., "Measurement of Structural Damping Using the Random Decrement Technique," *Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 53*, Pt. 4, pp 63-71 (May 1983).

107. Yang, J.C.S., Chen, J., and Dagalakis N.G., "Damage Detection of Off-Shore Structures by Random Decrement Technique," *J. Energy Res. Tech., Trans. ASME*, 106 (1), pp 38-42 (Mar 1984).

108. Yang, J.C.S., Tsai, T., Pavlin, V., and Chen, J., "Structural Damage Detection by System Identification Technique," *Shock Vib. Bull., U.S. Naval Res. Lab., Proc. #55*, Pt. 3, pp 57-66 (June 1985).

109. Yee, K.W. and Blomquist, E.S., "Rotating Tool Wear Monitoring Apparatus," Dept. Commerce, Washington, D.C., U.S. Patent No. 4 471 444.

110. Yoshikawa, T. and Fujiwara, T., "Application of Acoustical Emission Technique to Detection of Rolling Bearing Failure," *Acoustic Emission Monitoring Anal. Mfg., ASME*, New Orleans, LA, pp 55-75 (1984).

LITERATURE REVIEW:

survey and analysis
of the Shock and
Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four reviews each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

FRACTURE ANALYSIS -- A REVIEW

D. Brock*

Abstract. This article is a review of practical methods for fracture mechanics analysis. Linear elastic methods can yield useful results. Elastic-plastic methods are becoming useful with the development of simple expressions for J that contain only one geometry factor. Present limitations are due only to limited availability of geometry factors.

Fracture mechanics analysis based on linear elastic concepts developed in the 1960s has become established during the last decade as a practical analytic method for studying structural fracture. Its use has become institutionalized by damage tolerance requirements implemented in the late 1970s for both military and civil airplanes. Fracture analysis is also prescribed in the ASME boiler and pressure vessel code. During the last decade a fracture analysis method based on elastic-plastic concepts has emerged and become practical because simple expressions containing only one geometry parameter can be used for the fracture parameter.

This review emphasizes fracture analysis methods that are useful for predicting structural fracture; other developments are mentioned but not discussed in detail. The bases for the practical methods are presented with sufficient detail to enable the reader to appreciate similarities and differences. Because all fracture analysis, whether elastic or elastic-plastic, must be combined with collapse analysis, the latter is discussed first. Results and examples of the accuracy of the methods are presented after the discussion of concepts.

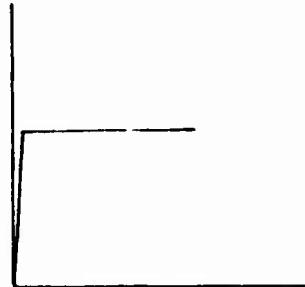
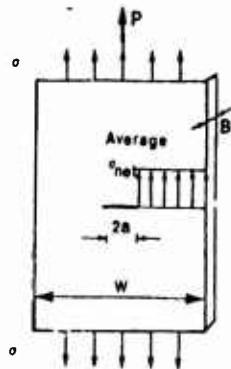


Figure 1. Maximum Load Carrying Capacity Reached at Net Section Yield for Ideally Plastic Material.

FRACTURE CONCEPTS

Collapse.

Although given a new name and a slightly different interpretation, collapse is the same as the classical limit load concept [1]. The limit load is reached when the average stress in the smallest section exceeds the yield stress. The concept is trivial for an ideally plastic material and a center crack as shown in Figure 1. After the stress equals the yield stress of the material, σ_y , the limit load, P_{lim} of a plate of width W and thickness B with a center crack of size $2a$ is:

$$P_{lim} = (W - 2a)B\sigma_y \quad (1)$$

The limit load is the highest load a panel can sustain under any circumstances; hence, the limit load is the absolute maximum failure load.

At the limit load the nominal stress in a panel is $\sigma_f = P_{lim}/WB$, so that the absolute maximum failure stress is:

$$\sigma_{fmax} = \frac{W - 2a}{W} \sigma_y \quad (2)$$

Note that for a center crack the failure stress depends linearly upon crack size, as illustrated in

* Fracture Research Inc., 9049 Cupstone Drive, Galena, Ohio 43021

Figure 2. For other geometries and other loading the limit load can be calculated just as easily.

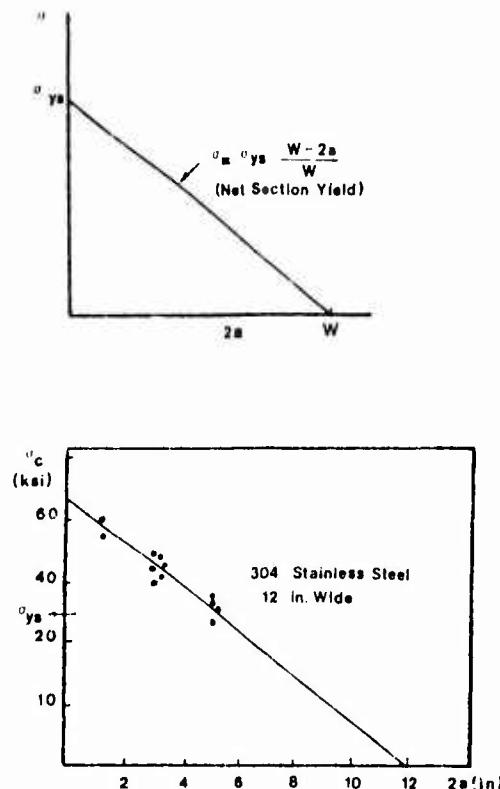


Figure 2. Net Section Yield and Net Section Collapse.

- Stress at net section yield for panel of width W and crack $2a$.
- Net section collapse in stainless steel [1].

For materials with slightly rising stress-strain curves the use of the yield stress in equation (2) is slightly conservative [2,3]. Materials that can be treated with linear elastic fracture mechanics usually belong in this category. No fracture mechanics analysis is complete without evaluation of the limit load. If the analysis indicates a fracture stress higher than the stress calculated by equations (2), failure will occur by collapse. The actual failure stress is the lower of the values calculated for fracture stress and stress at collapse by equation (2).

It was originally proposed [2] that fracture stress applied only in plane stress, but it also applies in plane strain. No matter how low the toughness, the calculated fracture stress for very small cracks will be higher than the yield. In such a case failure occurs by collapse. The

regime is similar for very large cracks. If a structure is very small, failure always almost occurs by collapse even if the toughness is low [2,3].

In the case of materials with considerable work hardening -- that is, for cases in which a large difference exists between yield stress and ultimate tensile stress -- equation (2) is too conservative. Thus, it has been proposed [1] that collapse load should be defined as the load at which the average net section stress is the collapse stress σ_{coll} , which is higher than the yield stress but less than the ultimate tensile strength. Although the value of the collapse stress can be measured readily in a test [1], it is often arbitrarily taken as equal to the average of the yield stress and the ultimate tensile stress [4].

Using collapse stress means that equation (1) and equation (2) become

$$P_{lim,collapse} = (W - 2a)\sigma_{coll} \quad (3)$$

and

$$\sigma_{f,max} = \frac{W - 2a}{W} \sigma_{coll} \quad (4)$$

The collapse load is the absolute highest load a structure can sustain regardless of any fracture mechanics, be it elastic or elastic-plastic. The stress at collapse $\sigma_{f,max}$ is the nominal stress at the collapse load; σ_{coll} is the average net section stress at collapse. Collapse load and stress at collapse must be evaluated in any fracture analysis. The actual failure stress is the lower of the values for calculated fracture stress and stress at collapse. Omission of this trivial step is one of the reasons why fracture predictions are often not conservative.

Linear elastic concept based on stress. The elastic stress distribution at the tip of an arbitrary crack in an arbitrary body subjected to arbitrary crack opening loading by tension or bending is given as [5].

$$\sigma_x = \frac{k}{\sqrt{2\pi x}} \quad (5)$$

where σ_x is the tensile stress on the section through the crack, and x the distance from the crack front (Figure 3). The stresses in other directions can be described in a similar manner.

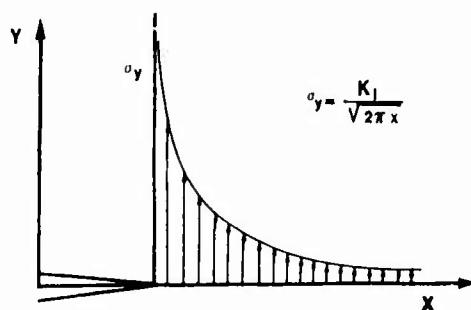


Figure 3. Crack Tip Stresses.

Because equation (5) is for an arbitrary case, it is valid for any and all crack tips. Crack tip stress σ_y apparently depends only on the parameter K , called the stress intensity factor. Equation (5) is for elastic stress; hence σ_y must be proportional to the applied stress σ_0 . Crack tip stress also depends upon crack size. For equation (5) to have the proper dimension, σ_y must depend upon the square root of crack size. Without any analysis it can readily be seen that

$$\sigma_y = \frac{K}{\sqrt{2\pi x}} = \frac{C\sigma_0\sqrt{a}}{\sqrt{2\pi x}}$$

so that

$$K = C\sigma_0\sqrt{a} \quad (6)$$

The numerical factor C depends upon geometry. Because equation (6) shows C as dimensionless, C can depend upon geometry only as $C = f(a/L)$. L is a characteristic length parameter. It has become common practice to replace C by β , with $\beta \propto \sqrt{\pi}$. This leads to equation (7).

$$K = \beta\sigma_0\sqrt{\pi a} \quad \text{with } \beta = f(a/L) \quad (7)$$

From equation (6) and equation (7) the crack tip stresses are known completely if β is known for the geometry at hand. Handbooks [6-8] for β exist; any of many procedures [9] can be used to determine β for new geometries.

The fracture criterion in linear elastic fracture mechanics (LEFM) states that fracture occurs when the crack tip stress field becomes critical. For σ_y in equation (6) to exceed a critical value, K must exceed a critical value. (This condition holds when a small amount of plastic deformation occurs at the crack tip [3].) If the

critical value of K is called K_c , the fracture criterion is that fracture occurs if

$$K \geq K_c \quad (8)$$

The critical value K_c is called the toughness of the material. Toughness depends upon the crack tip state of stress (plane stress or plane strain) [3]. Toughness is lowest for the case of plane strain and is generally denoted K_{Ic} . K_c denotes toughness in non-plane strain conditions. LEFM applies in the same manner in both cases.

The fracture criterion of equation (8) can be rewritten

$$\beta\sigma_f\sqrt{\pi a} = K_c \quad (9)$$

where σ_f is the applied stress. Thus, the stress at fracture is

$$\sigma_f = \frac{K_c}{\beta\sqrt{\pi a}} \quad (10)$$

The fracture condition is given by equation (10) whether or not the fracture toughness K_c is known. If the toughness is not known, fracture stress σ_f can be measured in a test and the toughness determined with equation (9). (Any specimen will suffice; there is no need to use a standard [10] specimen. If such a need existed the result would be useless for fracture predictions other than for that specimen.) If the toughness is known, the fracture stress of any structure with a crack follows from equation (10). The actual failure stress is the lower value of the stresses calculated by equation (2) and equation (10).

Linear elastic concept based on strain energy. Energy conservation requires that no energy is lost when a body is loaded. Therefore, the work F done by a load must equal the strain energy U in the body.

$$F = U = 0 \quad (11)$$

The equation holds when a body is cracked. But, if the crack propagates, a new energy term comes into play; namely the work of fracture W . If crack size equals a , fracture over a distance da would require a small quantity of energy dW . This energy must be delivered by another source, either F or U . In the process of frac-

ture over da , the work done by the load is dF , and the change in strain energy is dU . Energy conservation requires that [3,11]

$$\frac{d}{da} (F - U - W) = 0 \quad (12)$$

or

$$\frac{d}{da} (F - U) = \frac{dW}{da} \quad (13)$$

Equation (13) is a fracture criterion. Fracture over da will occur when equation (13) can be satisfied; i.e., if enough energy can be delivered to provide dW . If not enough energy is delivered, equation (11) remains in effect. Assigning different symbols to the terms in equation (13), allows the equation to be written in the form:

$$G = R \quad (14)$$

G is the released energy (energy release rate); R is the fracture resistance. Fracture will occur according to equation (14) when the released energy G is sufficient to deliver the required energy R . It can be shown [3] that the released energy is $G = K^2/E$, where E is Young's modulus. Equation (14) thus means that fracture occurs if

$$\frac{K^2}{E} = R \quad (15)$$

or

$$\frac{\beta^2 \sigma_n^2 a}{E} = R \quad (16)$$

In order for equation (16) to be the same as equation (9), R must equal K^2/E . The work of fracture is thus equal to the square of the toughness divided by the modulus.

R depends upon the amount of crack extension Δa [3]. The energy for fracture increases as fracture progresses. The conclusion is that fracture can be stable or unstable (uncontrollable). An uncontrollable fracture occurs when

$$\frac{dG}{da} > \frac{dR}{da} \quad (17)$$

The rising fracture resistance R is referred to as the R-curve. Fracture analysis based on equation (16) and equation (17) is referred to as the energy method, or the R-curve method. Its principles were established as early as 1960. Almost all material under all circumstances exhibit a rising R-curve; in cases of low toughness, the rise is so small that the curve is essentially flat.

Because $G = K^2/E = \beta^2 \sigma_n^2 a/E$, the condition of equation (17) is the point of tangency between the G curve and the R curve. The G-line is straight and is a function of a when $\beta = 1$. The slope of the line depends upon the stress. For the case shown in Figure 4a fracture begins at a_{ci} , proceeds stably from a_i to a_c , and becomes unstable at a_c . If the R-curve rises gently, as is often the case in plane strain, instability is immediate, so that the rise of the R-curve may go unnoticed.

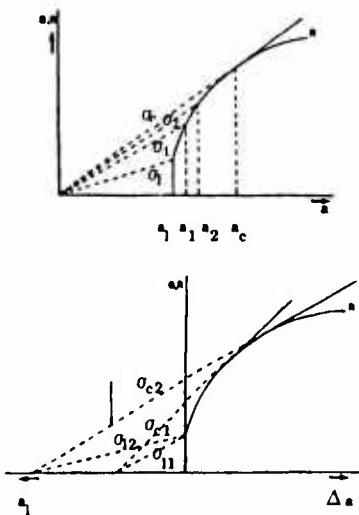


Figure 4. Energy Conservation Criterion for Fracture.

- a. R-curve and G-lines
- b. Instability points

Because Young's modulus can be divided out of equation (16), equation (16) and equation (17) can be rewritten

$$\left. \begin{aligned} k &= k_R \\ \frac{dk}{da} &> \frac{dk_R}{da} \end{aligned} \right\} \quad (18)$$

K_R is the same as \sqrt{ER} . The procedure does not change.

Elastic-plastic concept.

The most useful elastic-plastic fracture mechanics (EPFM) concept developed thus far is based on the energy conservation concept of equation (13) and equation (17). Unfortunately, the energy quantities involved have been given different names. The new name for G is J , and the new name for R is J_R . Thus, equation (14) becomes equation (19). Fracture occurs if

$$J = J_R \quad (19)$$

With the usual rising R-curve (now J_R -curve) equation (18) becomes:

$$\frac{dJ}{da} = \frac{dJ_R}{da} \quad (20)$$

Because of the original definition [12] the quantity J is known as the J -integral. However, it can be shown [3,12] that J is essentially the energy release rate. Equation (19) and equation (20) are valid for materials with nonlinear stress-strain curves and are therefore useful for EPFM.

The various mathematical expressions for J in approximate form are called estimation schemes. The most elegant solution is obtained when the plastic strain of a material can be expressed as

$$c_p = \frac{\sigma^n}{F} \quad (21)$$

in which n is known as the strain hardening exponent; and F is a plastic modulus. Note that for $n = 1$ and $F = E$ the equation reduces to Hooke's law, for which the energy equation for fracture is $G = R$. It is written

$$\frac{\beta^2 \sigma^2 \pi a}{E} = R \text{ or } \frac{\beta^2 \sigma^{n+1} a}{E} = R \quad (22)$$

A similar expression is obtained when n is not equal to 1 and F is not equal to E . In that case

$$\frac{H \sigma^{n+1} a}{F} = J_R \quad (23)$$

H is a geometric parameter similar to β , but H also depends on n .

Indeed, equation (23) is the plastic fracture criterion [3]. Unfortunately, instead of using equation (23) the developers of the geometric functions [13,14] elected to write equation (21) as

$$\frac{\epsilon}{\epsilon_0} = \left(\frac{\sigma}{\sigma_0} \right)^n \quad (24)$$

Where σ_0 is called the flow stress and $\epsilon_0 = \sigma_0 / E$. The stress σ_0 is only a reference stress that can be chosen arbitrarily at any value so long as $\epsilon_0 = \sigma_0 / E$ and

$$\alpha = \frac{\sigma_0^n}{\epsilon_0 F} \quad (25)$$

Thus, calling σ_0 the flow stress suggests incorrectly that this arbitrary reference stress should have physical significance.

This new definition of the stress-strain curve also changes the fracture equation from equation (23) into

$$\alpha \sigma_0 \epsilon_0 c h_1 \left(\frac{P}{P_0} \right)^{n+1} = J_R \quad (26)$$

Compare equation (23) and equation (26); it appears that crack size a is replaced by the uncracked ligament c and that the geometric function H is replaced by h_1 . Stress is replaced by load P ; load P_0 is introduced. P_0 is the limit load if σ_0 were the collapse stress, but, because σ_0 is arbitrary, P_0 is a fictitious limit load. It is trivial that c , P_0 , and P are related to a , σ_0 , and σ by geometric functions. Equation (25) can be used to reduce fracture equation (26) readily [15] to equation (23).

Equation (26) raises the false expectation that fracture stress depends upon collapse load. The collapse load is indeed the limiting condition, but this condition must be evaluated separately. Equation (26) does not account for collapse load

because it is equivalent to equation (23). Artificial introduction of a limit load to equation (26) does not make the fracture stress dependent upon this limit load [15].

Equation (20) and equation (23) can be used if elastic deformations can be neglected. Otherwise the elastic energy release must be included. Fracture thus occurs if

$$G + J = J_R \quad (27)$$

Equation (27) requires combination of equation (16) and equation (23) or equation (26).

In EPFM the toughness is given by J_R , which is a rising curve as a function of the amount of crack extension Δ_a , just as the R-curve discussed previously. This toughness can be obtained from a test that involves measuring the fracture stress to evaluate equation (23) to obtain J_R . After J_R is known, equation (23) can be used to calculate the fracture stress of a structure for which $H(h_1)$ is known [13,14]. Note that the actual failure stress is still the lower value of the stress calculated from equation (4) and equation (23). Failure occurs by collapse if the collapse stress on the net section is reached before the fracture condition. Collapse is still the limiting condition and must be evaluated separately.

Another estimation scheme is generally used [16] to obtain J in a test. Because J is the energy release rate, J_R equals the energy release rate at fracture. Energy release can be expressed as the change in strain energy; strain energy can be related to the load-displacement curve. Appropriate simplifications and assumption can be used to obtain directly an approximate value for J from the load-displacement diagram, provided the displacement is due only to the crack. If a compact tension specimen is used, virtually all displacement is due to the crack. Thus, J_R is obtained from the area under the load-displacement diagram. Attempts have been made to use the reverse procedure to predict structural fracture [17]; the results are debatable however, because grossly simplifying assumption must be made to obtain the displacement-due-to-the-crack-only of a cracked structure.

Variations on the theme.

The most commonly used alternative criteria for fracture are based upon crack (tip) opening displacement [18] or crack opening angle [19]; that is, fracture occurs when the crack opening displacement exceeds a critical value. These

criteria are not really different from those discussed above. Both quantities can be expressed directly [13,14] in G or J ; the critical values of these quantities can be directly expressed in R or J_R by the same mathematical relation. Therefore, the fracture criteria are identical to equation (10) and equation (23). The criteria chosen are a matter of personal preference unless certain ones can be more easily measured in a test.

Crack tip opening quantities can be measured directly; R and J_R must be obtained by mathematical manipulation from other measurements. Direct measurement may be useful for obtaining the material property that represents toughness (e.g., critical COD). Alternative criteria do not provide anything new or make anything easier. If the criteria discussed in previous sections work, those based on crack tip opening will work.

Other alternative approaches often introduce an artificial second parameter [3,20]. A cleverly selected second parameter can eliminate some anomalies but usually introduces new ones. One of the oldest parameters is the so-called plastic zone correction [3]. The crack size a is artificially increased to $a + r_p$; r_p is the plastic zone at fracture given by

$$r_p = \frac{K_c^2}{b^2 \pi \sigma^2} \quad (28)$$

Substitution of $a + r_p$ for a in equation (9) gives as the fracture condition

$$\beta \sigma_f \sqrt{(a + K_c^2 / b^2 \pi \sigma_u^2)} = K_c \quad (29)$$

Although this equation seemingly solves a problem, it introduces a new anomaly: if $a = 0$ the predicted fracture stress is $b\sigma_{ys}/\beta$. To obtain a fracture stress equal to σ_u , the ultimate tensile strength at $a = 0$ (if $\beta = 1$) is

$$\sigma_f \sqrt{(a + K_c^2 / \pi \sigma_u^2)} = K_c \quad (30)$$

Equation (28) and equation (29) are two-parameter fracture criteria. Many more can be created

in a similar manner. Some will work; however, most will not because they are artificially constructed and misrepresent the problem.

The tearing modulus concept seems to be a new approach but is the same as equation (17), which was established in the late 1950s. The quantities in the equation are made dimensionless by multiplication of both sides by E / σ_{ys}^2

$$(E / \sigma_{ys}^2)(dJ / da) \geq (E / \sigma_{ys}^2)(dJ_R / da) \quad (31)$$

The quantities in the equation are then given new symbols

$$T \geq T_{material} \quad (32)$$

where T is called the tearing modulus. Equation (32) is nothing more than another form of equation (17).

The so-called R6 approach is not a new approach. The concept was originally proposed in England [21] and is now being suggested [22] as an alternative fracture criterion, which it is not. The concept merely recognizes that fracture occurs when $K = K_c$ or that collapse occurs when net section stress equals collapse stress. The result is the fracture locus shown in Figure 5. The curved part of the fracture locus cannot be defined other than by a plastic fracture criterion. In the R6 approach the curved part is defined on the basis of J_R . The curve is then (with some modifications) used to predict fracture. If the criteria based on K and J , as discussed in the previous sections, are applicable, the R6 approach is useful. If the R6 approach leads to different answers, it is because the material properties used as input are different (which they should not be) or simplifications or errors were introduced.

Other fracture problems.

The fracture criteria discussed above have been developed to the point of practical application. For some time research has been in progress in applying these criteria to nonstructural materials such as rocks and eye glasses and to structural materials of the future such as ceramics and composite materials. Applications to brittle and semi-brittle materials are relatively straight forward; applications to composite materials are not.

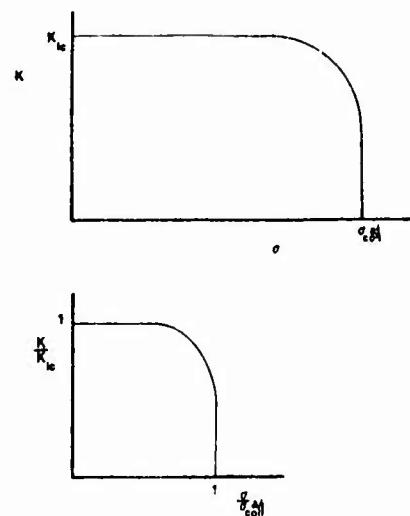


Figure 5. Fracture analysis Diagram [21].

- a. Fracture locus
- b. Normalized diagram

Research on fracture mechanics of composites has not yet passed the point of testing and material characterization. The meaning of test results is often not understood; the criteria used are often primitive [23].

Another area of research, dynamic fracture, is of special interest with regard to armor and weapons penetration. Considerable progress has been made [24]. In essence the fracture condition of equation (13) is modified to account for another energy term, the kinetic energy. The fracture resistance J_R or R is different; it accounts for strain rate sensitivity of the material.

APPLICATIONS

The usefulness of LEFM for structural fracture predictions is well established. Fracture of a cracked structure can be predicted on the basis of equation (10). The geometric factor for the structural crack must be obtained first. Among various procedures for obtaining , the most common and simple one is superposition and compounding of solutions compiled in handbooks [6-8]. For a certain crack size the fracture stress follows from equation (10). Solving the equation for a range of crack sizes provides a residual strength diagram; i.e., the remaining structural strength in the presence of a crack as a function of crack size.

Care should be taken that the collapse or limit load condition is also evaluated. The actual failure stress is the lower of the value calculated for fracture stress and the stress at collapse. In many cases the collapse condition prevails; e.g., Figure 6. Failure to assess collapse is one of the reasons LEFM is claimed to have limited use; but combination of collapse analysis and LEFM can solve many fracture problems with accuracy. Figure 7 compares predicted fracture stresses for cracks at holes with actual test data [25].

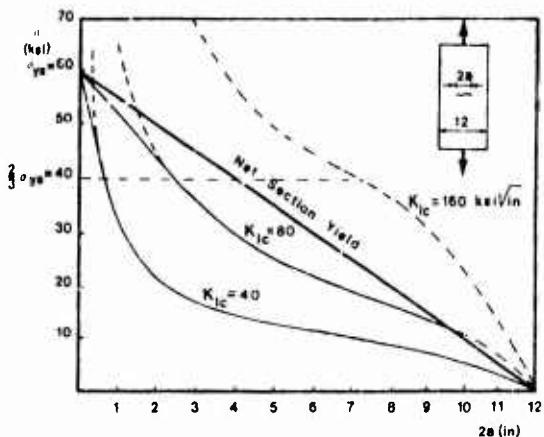


Figure 6. Cases of Elastic Fracture and Collapse.

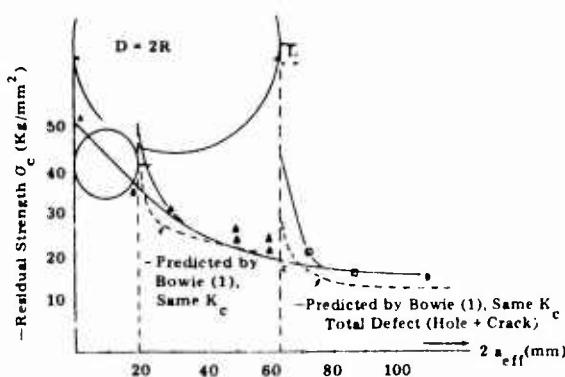


Figure 7. Predictions of Fracture Stress for Cracks at Holes and Test Data [25].

Fracture prediction by EPFM requires solution of equation (23) or equation (26). The geometric factor H (or h_1) must be known. If the use of EPFM is still somewhat limited, it is because geometric factors are available for only a few geometries [13,14]. Extensive applications will require the generation of many more geometric factors. At present only problems for which H

is available can be solved; e.g. cracks in cylinders. A simple method for estimating H on the basis of β has been proposed [15]. In the case of EPFM the failure stress is the lower value of the stress calculated at collapse and the predicted fracture stress. Failure stress can then be predicted with reasonable accuracy [4,15] as shown in Figure 8 and Figure 9. The collapse load is sometimes inaccurate because the collapse stress was not measured; rather, it was arbitrarily assumed to be equal to the average of yield stress and ultimate tensile stress.

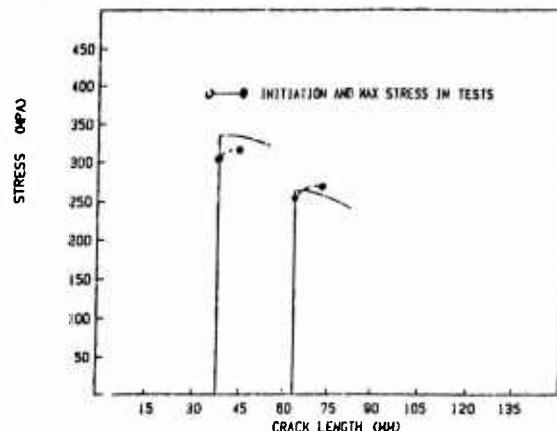


Figure 8. Elastic-Plastic Fracture Predictions [15] and Test Results [4].

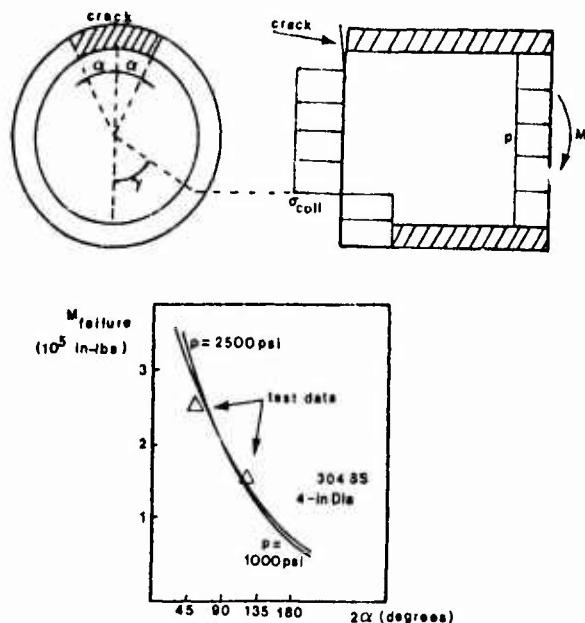


Figure 9. Failure by Collapse of Cracked Stainless Steel Pipe [1].

- Collapsing analysis model
- Predicted curves and test data

Typical J_R curves are shown in Figure 10. J can vary, depending on the way the test is evaluated. Consider equation (23); a slight error in stress or load calculation has a very large effect on J_R . That is when $n = 9$ an error of 5% in stress leads to an error of $(1.05)^{10} = 1.63$ or 63% in J_R . (Similar errors occur with other estimation schemes for the same reason; namely the gentle slope of the load-displacement curve.) On the other hand, if these J_R values are used to predict a fracture stress, an error of 63% in the toughness J_R would cause an error of only 5% in fracture stress if $n = 10$. Thus, EPFM is very forgiving. Reasonable results can be obtained even with approximate values.

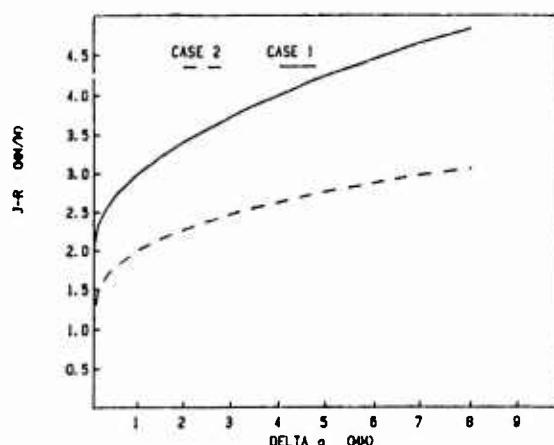


Figure 10. J_R -Curves for Stainless Steel.

Other fracture criterias, if they are applied correctly, should give the same answers. The criteria based on crack tip displacements are identical for the J -criterion. Thus, different results are due to interpretations of tests used to obtain material parameters, use of approximations, or errors in any of the procedures used. That different J -estimation schemes may lead to different results is an indication of the accuracy of a J estimate, not of a fracture analysis.

Fracture analysis is an inherently inaccurate process because of scatter in material properties. Yield stress and ultimate tensile strength are measured for the bulk of the test coupon (integrated over the coupon). On the other hand, fracture properties are only for the small amount of material that happens to be at the crack tip at the time of fracture. Thus, the lack of homogeneity of the material plays a much larger role in determining scatter. Fracture in the structure is affected. LEFM toughness values typically scatter by 15%. Therefore the fracture stress prediction can be off by 15%.

This is not a shortcoming of fracture mechanics but is due to less-than-ideal material behavior. In this respect EPFM is an advantage because the method is forgiving.

CONCLUSION

Progress in fracture analysis during the last decade has been in the consolidation of linear elastic methods (LEFM). LEFM in combination with collapse analysis provides answers to most structural fracture problems. A usable elastic-plastic method (EPFM), which must be used in combination with collapse analysis, has also been developed. EPFM has become useful in a practical sense due to the development of a J -estimation scheme that permits an expression for J with only one geometric parameter, as in the case of K . Present limitations are due to limited availability of geometry factors. Fracture analysis methods not based on K or J are essentially equivalent to geometric factors and should give the same results unless errors are made in interpretation or simplification. Fracture analysis of metals and ceramics yields useful results considering the inherent inaccuracy of fracture analysis due to scatter in material behavior. Fracture analysis procedures of composites are nonexistent; research in this area is in the material-characterization stage.

REFERENCES

1. Kanninen, M.B. et al., "Towards an Elastic-Plastic Fracture Mechanics Capability for Reactor Piping," Nuclear Engrg. Des., 48, pp 117 (1976).
2. Feddersen, C.E., "Evaluation and Prediction of the Residual Strength of Center Cracked Tension Panels," ASTM STP 486, pp 50-78 (1971).
3. Broek, D., Elementary Engineering Fracture Mechanics, Nijhoff, 3rd Ed. (1982).
4. Wilkowski, G.M. et al., "Degraded Piping Program - Phase II," NURFG/CR-4082 (1985).
5. Paris, P.C. and Sih, G.C., "Stress Analysis of Cracks," ASTM STP 381, pp 30-81 (1965).
6. Tada, H. et al., The Stress Analysis of Cracks Handbook, Del Research Corp. (1973).
7. Sih, G.C., Handbook of Stress Intensity Factors, Lehigh Univ. Press (1973).

8. Rooke, D.P. and Cartwright, D.J., Compendium of Stress Intensity Factors, H.M. Stationery Office (1976).
9. Rooke, D.P. et al., "Simple Methods of Determining Stress Intensity Factors," AGARDograph 257 (1980).
10. The Standard KIC Test, ASTM Standard E-399.
11. Griffith, A.A., "The Phenomena of Rupture and Flow in Solids," Phil. Trans. Royal Soc., Ser. A, 221, pp 163-197 (1921).
12. Rice, J.R., "A Path Independent Integral and the Approximate Analysis of Strain Concentrations by Notches and Cracks," J. Appl. Mech., Trans. ASME, pp 379-386 (1968).
13. Kumar, V. et al., "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI NP-1931 (1981).
14. Kumar, V. et al., "Advances in Elastic-Plastic Fracture Analysis," EPRI NP-3607 (1984).
15. Broek, D., "J Astray and Back to Normalcy," Paper to European Congress of Fracture (1986).
16. Merkle, J.G. and Corten, H.T., "A J-integral Analysis for the Compact Specimen Considering Axial Force as well as Bending Effects," J. Pressure Vessel Tech., 96, pp 286-292 (1974).
17. Paris, P.C. and Tada, H., "The Application of Fracture Mechanics Methods Using Tearing Instability Theory to Nuclear Piping Postulating Circumferential through Wall Cracks," NUREG/CR-3464 (1983).
18. Burdekin, F.M. and Stone, D.E.W., "The Crack Opening Displacement Approach to Fracture Mechanics in Yielding," J. Strain Anal., 1, pp 145-153 (1966).
19. Kanninen, M.F. et al., "Instability Predictions for Circumferentially Cracked Type 304 SS Pipes Dynamic Loading," EPRI NP-2347 (1982).
20. Newman, J.C. and Loss, F.J. (eds.), Elastic-Plastic Fracture Mechanics Technology, ASTM STP 896 (1985).
21. Chell, G.C., "A Procedure for Incorporating Thermal and Residual Stresses into the Concepts of a Failure Analysis Diagram," ASTM STP 668 (1979).
22. Bloom, J.M., "Deformation Plasticity Failure Assessment Diagram," ASTM STP 896, pp 114-127 (1985).
23. NASA, Tough Composite Materials, Noyes Publ. (1985).
24. Hahn, G.T. and Kanninen, M.F. (eds.), Fast Fracture and Crack Arrest, ASTM STP 627 (1977).
25. Broek, D. and Vlieger, H., "Cracks Emanating from Holes in Plane Stress," Intl. J. Fract. Mech., 8, pp 353-356 (1972).

BOOK REVIEWS

PROBLEMS IN PERTURBATION

Ali H. Nayfeh
John Wiley & Sons, New York, NY
556 pages + xi, 1985

The development of the theory of nonlinear differential equations has promoted the study of several engineering problems that were regarded difficult in the past. The theory helped engineers to understand complex system characteristics that could not be explained within the framework of the linear theory of differential equations. The importance of nonlinear theory has been realized by several schools that currently offer courses in nonlinear vibrations or nonlinear differential equations. Although there are several books on nonlinear oscillations and differential equations, students and researchers frequently encounter difficulties concerning the applicability of existing theories of perturbation techniques. Professor Nayfeh is an authority in perturbation methods and his book Problems in Perturbation contains detailed solutions of all the problems in his earlier book Introduction to Perturbation Techniques (John Wiley & Sons, 1973). The book contains 15 chapters; each chapter is followed by a number of solved problems and an equal number of unsolved supplementary problems.

The first four chapters contain a mathematical background of basic concepts and methods for solving nonlinear differential equations. Chapter 1 presents definitions of parameter and coordinate perturbations, gauge functions, order symbols, asymptotic series and expansions, and nonuniform expansion. Chapter 2 summarizes a number of methods for solving algebraic and transcendental equations. Differential equations, the solution of which is represented in the form of integrals, are outlined in chapter 3. They include asymptotic expansions of functions defined by definite integrals, expansions of integrands, integration by parts, Laplace's method, method of stationary phase, and the method of steepest descent. Several integrals encountered in differential equations are given as exercises. Chapter 4 treats nonlinear differential equations of conservative systems. Applications of the Lindstedt-Poincare method, the method of renormalization, the method of multiple scales, and

the method of averaging are well demonstrated with a number of solved problems.

Chapters 5 and 6 deal with free oscillations of nonlinear systems with sources of positive and negative damping respectively. Although both the Lindstedt-Poincare technique and the method of renormalization account for the shift in frequency caused by the perturbation, they do not adequately provide approximations to the transient response for the problems because neither accounts for variations in amplitude. In contrast, both the method of multiple scales and the method of averaging provide uniform expansions for the transient response. Chapter 7 considers the free oscillations of undamped systems with quadratic and cubic stiffness nonlinearities. For these systems the Lindstedt-Poincare technique, the method of renormalization, the method of multiple scales, the generalized method of averaging, or the Krylov-Bogoliubov method can be used to derive approximate solutions.

Chapters 9 through 11 deal with the responses of nonlinear systems when subjected to different types of external excitations. External harmonic excitations are considered in chapter 9, multi-frequency excitations are treated in chapter 10, and parametric excitations are analyzed in chapter 11. In chapter 9 the method of multiple scales is used for solving systems with quadratic nonlinearity; the methods of averaging and multiple scales are used to treat systems with cubic nonlinearity. Systems with quartic nonlinearity are solved using the straightforward expansion, the method of multiple scales, and the averaging method. In chapter 10 on multi-frequency excitations the author introduces possible resonance conditions that depend on the number of excitation components and the order of nonlinearity. Methods of multiple scales, averaging, or Krylov-Bogoliubov are used to determine amplitude and phase of the response. For parametric excitations (chapter 11) the method of strained parameters and Whittaker's technique are used to determine the stability regions of linear systems. When nonlinearity is included, Floquet theory fails to predict the response limit cycle. In this case the author recommends the methods of multiple scales, averaging, or Krylov-Bogoliubov to determine uniform expansions for linear as well as nonlinear systems with periodic and non-periodic coefficients.

Chapter 12 deals with a different class of differential equations known as boundary-layer problems. These problems are described by linear or nonlinear differential equations with variable coefficients; the highest derivative is multiplied by a small parameter. The differential equations are usually handled by fast, magnified, or stretched scales. The mathematical techniques used with these problems include the method of matched asymptotic expansions, the method of composite expansions, and the method of multiple scales. Because of the versatility and effectiveness of the method of matched asymptotic expansions, the author briefly outlines this method and demonstrates its application to a number of solved problems the solutions to which are also obtained by other methods.

The asymptotic solutions of linear ordinary differential equations with variable coefficients in the neighborhood of a given finite point are analyzed in chapter 13. The conditions under which asymptotic solutions are developed are outlined in terms of the nature of the point in question and its relation to the coefficients of the differential equation. Chapter 14 treats approximate solutions of differential equations with a large parameter. The Liouville problem is selected as a model for demonstrating the WKB method and the Langer transformation.

Chapter 15 deals with essential solvability conditions in perturbation techniques. The origin of these conditions is due mainly to the presence of secular or resonance terms that appear in higher-order perturbational equations. In other cases, such as boundary value problems, the perturbational equations may not possess solutions unless certain conditions are satisfied. The solvability conditions for vibration and boundary-value problems are well demonstrated with a number of solved problems. This chapter is the corner-stone of perturbation techniques; the solved problems serve several engineering applications.

The book succeeds in meeting its main objectives: to provide researchers and graduate students with an excellent account of perturbation techniques and an extensive number of supporting solved problems.

R.A. Ibrahim
Professor of Mechanical Engineering
Texas Tech University
Department of Mechanical Engineering
Lubbock, Texas 79409

**EARTHQUAKE DESIGN OF
CONCRETE MASONRY BUILDINGS --
VOL. I**

R.E. Englekirk, G.C. Hart, and Concrete
Masonry Assoc. of California and Nevada
Prentice Hall, Inc., Englewood Cliffs, NJ
1982, 144 pp

This book is the first in a three-volume set for the earthquake design of concrete masonry buildings. It presents the background material required to calculate earthquake loads on buildings by means of response spectrum analysis. The authors have taken care to present this material in a simple, understandable form. The reader is not expected to have a knowledge of structural dynamics or a familiarity of earthquake terminology or design codes. The book is brief, consisting of six chapters and only 144 pages.

The six chapters provide 1) a brief overview of the concepts of earthquake design; 2) a limited introduction to common terms used in earthquake engineering, including an introduction to earthquake response spectrum; 3) the earthquake design approach used in the Uniform Building Code; 4) methods used to obtain a simple stiffness and mass model of shear wall buildings; 5) the elastic analysis of a simple system using elastic response spectra; and 6) the inelastic analysis of a simple system using inelastic response spectra. The two Appendices provide a description of a geotechnical consultant's role in earthquake design and an introduction to multi-degree-of-freedom response spectra analysis.

Several well-chosen examples provide clear demonstrations of the techniques. This book should be well received by those who desire a working knowledge of simplified methods of earthquake analyses.

S.E. Benzley
Professor of Civil Engineering
Brigham Young University
Provo, Utah 84602

SHORT COURSES

1987

JANUARY

VIBRATION DAMPING TECHNOLOGY

Dates: January, 1987

Place: Clearwater, Florida

Objective: Basics of theory and application of viscoelastic and other damping techniques for vibration control. The courses will concentrate on behavior of damping materials and their effect on response of damped systems, linear and nonlinear, and emphasize learning through small group exercises. Attendance will be strictly limited to ensure individual attention.

Contact: David I. Jones, Damping Technology Information Services, Box 565, Centerville Branch USPO, Dayton, OH 45459-9998 - (513) 434-6893.

FEBRUARY

RANDOM VIBRATION IN PERSPECTIVE — AN INTRODUCTION TO RANDOM VIBRATION AND SHOCK, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION, WITH EMPHASIS ON STRESS SCREENING

Dates: February 2-6, 1987

Place: Santa Barbara, CA

Dates: March 9-13, 1987

Place: Washington, D.C.

Dates: April 6-19, 1987

Place: Ottawa, Ontario

Dates: June 1-5, 1987

Place: Santa Barbara, CA

Dates: August 17-21, 1987

Place: Santa Barbara, CA

Dates: October 19-23, 1987

Place: Copenhagen, Denmark

Objective: To show the superiority (for most applications) of random over the older sine vibration testing. Topics include resonance, accelerometer selection, fragility, shaker types, fixture design and fabrication, acceleration/power spectral density measurement, analog vs digital controls, environmental stress screening (ESS) of electronics production, acoustic (intense noise) testing, shock measurement and testing.

This course will concentrate on equipment and techniques, rather than on mathematics and theory. The 1984 text, "Random Vibration in Perspective," by Tustin and Mercado, will be used.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 682-7171.

ROTATING MACHINERY VIBRATIONS

Dates: February 9-11, 1987

Place: Orlando, Florida

Objective: This course provides participants with an understanding of the principles and practices of rotating machinery vibrations and the application of these principles to practical problems. Some of the topics to be discussed are: theory of applied vibration engineering applied to rotating machinery; vibrational stresses and component fatigue; engineering instrumentation measurements; test data acquisition and diagnosis; fundamentals of rotor dynamics theory; bearing static and dynamic properties; system analysis; blading-bearing dynamics examples and case histories; rotor balancing theory; balancing of rotors in bearings; rotor signature analysis and diagnosis; and rotor-bearing failure prevention.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254.

APPLIED VIBRATION ENGINEERING

Dates: February 9-11, 1987

Place: Orlando, Florida

Objective: This intensive course is designed for specialists, engineers and scientists involved with design against vibration or solving of existing vibration problems. This course provides participants with an understanding of the principles of vibration and the application of these principles to practical problems of vibration reduction or isolation. Some of the topics to be discussed are: fundamentals of vibration engineering; component vibration stresses and fatigue; instrumentation and measurement engineering; test data acquisition and diagnosis; applied spectrum analysis techniques; spectral analysis techniques for preventive maintenance; signal analysis for machinery diagnostics;

random vibrations and processes; spectral density functions; modal analysis using graphic CRT display; damping and stiffness techniques for vibration control; sensor techniques for machinery diagnostics; transient response concepts and test procedures; field application of modal analysis for large systems; several sessions on case histories in vibration engineering; applied vibration engineering state-of-the-art.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254

MACHINERY VIBRATION ANALYSIS I

Dates: February 24-27, 1987

Place: San Diego, California

Dates: August 18-21, 1987

Place: Nashville, Tennessee

Dates: November 17-20, 1987

Place: Oak Brook, Illinois

Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MARCH

MEASUREMENT SYSTEMS ENGINEERING SHORT COURSE

Dates: March 9-13, 1987

Place: Phoenix, Arizona

Objective: Electrical measurements of mechanical and thermal quantities are presented through the new and unique Unified Approach to the Engineering of Measurement Systems. Test requestors, designers, theoretical analysts, managers, and experimental groups are the audience for which these programs have been designed. Cost-effective, valid data in the field and in the laboratory, are emphasized. Not only how to do that job, but how to tell when it's been done right.

Contact Peter K. Stein, Director, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603 and (602) 947-6333.

MEASUREMENT SYSTEMS DYNAMICS SHORT COURSE

Dates: March 16-20, 1987

Place: Phoenix, Arizona

Objective: Electrical measurements of mechanical and thermal quantities are presented through the new and unique Unified Approach to the Engineering of Measurement Systems. Test requestors, designers, theoretical analysts, managers, and experimental groups are the audience for which these programs have been designed. Cost-effective, valid data in the field and in the laboratory, are emphasized. Not only how to do that job, but how to tell when it's been done right.

Contact Peter K. Stein, Director, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603 and (602) 947-6333.

MAY

ROTOR DYNAMICS & BALANCING

Dates: May 4-8, 1987

Place: Syria, Virginia

Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing, including

turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254

NOVEMBER

VIBRATIONS OF RECIPROCATING MACHINERY AND PIPING

Dates: November 10-13, 1987

Place: Oak Brook, Illinois

Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory -- including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compres-

sors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254

MODAL TESTING OF MACHINES AND STRUCTURES

Dates: November 17-20

Place: Oak Brook, Illinois

Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254

REVIEWS OF MEETINGS

57th SHOCK AND VIBRATION SYMPOSIUM

14-16 October, 1986
Monteleone Hotel
New Orleans, Louisiana

The 57th Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in New Orleans in October. It was hosted by the Defense Nuclear Agency and the U.S. Army Engineer Waterways Experiment Station. The formal technical program consisted of more than 60 papers (see Vol. 18, No. 9 of the Digest for the complete program; papers will be published in the Shock and Vibration Bulletin). Plenary sessions were conducted during the Symposium. Plenary A was given on nondevelopment items from a manager's point of view by Robert H. Lehnes of the U.S. Army Communications-Electronics Command, Ft. Monmouth, New Jersey. Plenary B was given by Dr. Allen J. Curtis of Hughes Aircraft Company titled "Dynamic Testing -- Seven Years Later". The talk of Dr. Curtis was referenced to an assessment of the area seven years earlier. An interesting session on short discussion topics covering many areas of mechanical vibration and shock was given on Thursday afternoon. A comprehensive workshop on nondevelopment items including methods and case histories was given on Wednesday. Dr. J. Gordon Showalter, Acting Director of SVIC, the members of the SVIC staff, and the program committee are to be congratulated for the assembly of an outstanding program on shock and vibration technology. Among the participants were representatives of the federal government, industry, academic institutions, and foreign nationals. The combination of formal and informal technical programs effected a meaningful transfer of shock and vibration technology. This Symposium was of particular interest to many persons who attended for years because of the uncertainty of its continuation (see Rattlespace).

The Opening Session

An extended welcoming address was given by Dr. Robert W. Whalin, Technical Director of the U.S. Army Engineer Waterways Experiment Station (WES). In view of the fact that a site visit was not practical, a detailed description of the WES facility and its activities was provided by Dr. Whalin. WES, one of four U.S. Army Corp

of Engineers' laboratories, works for sponsors in the military and civil areas. It is composed of the Environmental, Hydraulics, Information Technology, Geotechnical, and Structures laboratories and the Coastal Engineering Research Center. The Information Technology Laboratory has a computer program library and does software evaluation. The Environmental Laboratory is involved in toxic and hazardous waste and aquatic water plant research. The Hydraulic Laboratory performs structural math modeling, flood control modeling, and ship and tow simulation. The spectral wave generator of the Coastal Engineering Research Center and 42 ton dolos water breakers were described by Dr. Cohalin. The Geotechnical Laboratory of WES does earthquake engineering studies as well as vehicle wheel and track experiments. The Structures Laboratory is involved in modeling such facilities as the Richard Russell Dam. Some of the shock and vibration related research projects currently being performed at WES were described. Defense Nuclear Agency research on underwater cratering was described along with numerical models of projectile impact and penetration. Finally, hardened silo component tests were described by Dr. Whalen.

The keynote address was given by Dr. Eugene Sevin of the Office of the Secretary of Defense on "ICBM Modernization -- A Shock and Vibration Perspective". In his background remarks on the ICBM program, Dr. Sevin noted the political and technological implications of this program -- to provide protection within political bounds. He noted that the MX-Peacekeeper, the largest missile allowed by SALT II, has had many basing schemes -- from hard underground structures to mobile deployment. However, it has been found that the public does not like missiles roving around the countryside. Therefore the use of public land was explored. Dr. Sevin discussed the effect of overpressure on vulnerability and the different results obtained from tests using similar overpressures. As a result of uneven test results a boundary layer effect was postulated and a new test method evolved. Land based hardened missile launchers subjected to testing were shown to illustrate test results. The dense pack concept of the early eighties and its associated problems were described. He noted that the super hard silos have been revived. However, both super hard silos and hard mobile

launchers have their problems. It is a tradeoff between hardness and mobility. An alternative would involve concealment of small missiles among a large number of shelters. All these concepts have important shock and vibration considerations. Dr. Sevin showed the shock isolation aspects of super hard silo concepts along with new stronger concrete materials -- properties that approach the strength and ductility of mild steel. Stress time behavior in the silos where peak stress decays prior to bottom silo loading was discussed with respect to material properties and site geology. Missile shock isolation solutions were discussed in detail. Acceleration versus rattlespace is always a consideration. The rattlespace can be decreased by using a canister which distributes the loads better. Liquid springs have given way to foam and crushable elements. The effect of backfill in mitigating shock waves prior to reaching the silo was discussed. This increases the shock isolation system limit performance.

Progress made since the 46th Symposium in simulation of weapons effects was discussed. The HEST tests are improved with greater progress in understanding the air blast phenomenon and the simulation of it. However, thermal effects still need work. The improved new techniques involve the gas dynamic and wall jet physics of the event. Use of lower molecular weight gas to simulate nuclear event was discussed. Dr. Sevin showed an example of a test setup in a 40 acre field.

In closing, he noted the desirability of a continuing Shock and Vibration Symposium with a rotating sponsor system similar to the present arrangement; and, he is looking forward to a DNA-WES sponsored Symposium four years from now.

The second invited speaker in the opening session was Mr. Bob O. Benn of the U.S. Army Corps of Engineers Military Research and Development Programs. He gave an overview of their programs and laboratories. The activities of the Cold Regions Research and Engineering Lab at Hanover, New Hampshire, the Civil Engineering Lab (CERL) at Champaign, Illinois, the Waterways Experiment Stations (WES) at Vicksburg, Michigan, and the Engineering Topology Lab at Ft. Belvoir, Virginia were described. The labs at CERL and WES are of direct interest to the shock and vibration community. At CERL installation and facility planning, engineering materials, environmental qualification, and construction management are principal activities. Funding relationships and customer services were discussed for the WES facility, which does military and civil basic and applied research.

The Plenary Sessions

Plenary Session A was chaired by Rudy Volin of SVIC who commented on the motivations for the plenary and subsequent workshop on nondevelopment items -- cost savings versus the qualification of nondevelopment items.

The speaker for the plenary or nondevelopment items was Robert H. Lehnes of the U.S. Army Communications-Electronics Command, Ft. Monmouth, New Jersey. He described the Mobile Subscriber Equipment (MSE) communications program which is nondevelopment based. He described the bidding system, performance specifications, and encouragement to use commercial equipment. The standard acquisition life cycle was compared to the MSE life cycle. The shock and vibration requirements of the nondevelopment items were discussed. He noted that this method is not a panacea but costs and time can be saved.

The second plenary presentation was given by Dr. Allen J. Curtis of Hughes Aircraft Company on dynamic testing. Dr. Curtis noted that seven years ago at the Symposium he discussed three limitations in test engineering -- low cost screening systems, multiplexible controllers, and on-line response control testing. Advances have been made in low cost screening. He noted that it is best to have tests done in the manufacturing area -- people see results immediately. Some progress has been made in multiplexible controllers; however the need has evaporated since one test at a time has become acceptable. No advances have been made on on-line response control testing. He noted that we still have over conservative testing which is costly. It is related to inadequate analytical and experimental treatment of impedance effects.

Dr. Curtis discussed new development in testing specifications -- the issuance of MIL STD 810D, flexibility of digital controllers, and the maturing of screening, TAAF, and CERT testing. We have found that we do not have to combine environments. There are problems with inconsistent requirements -- qualification and reliability tests. Screening should be separate from acceptance testing.

Dr. Curtis gave a preview of the results from a study on screening. He showed relationships between flaws remaining versus time which were developed in the study -- after screening field failures are reduced. The screening test must be accelerated -- otherwise failures follow normal pattern. He showed a graph of the ratio of flaws out to in versus screening level -- thus establishing an optimum level.

Dr. Curtis described the innovative use of digital controllers including some history of their use. He showed a helicopter example and transient testing to achieve different load factors in different parts of the equipment. He noted that the tuned transient was quite practical when generated by a digital controller. Slewing in small steps lets the controller maintain control.

In his concluding remarks Dr. Curtis, who gave his first Symposium paper in 1956, thanked the SVIC for its service to the shock and vibration community and their role in the development of shock and vibration technology.

The Technical Sessions

Technical sessions were held on instrumentation, shock analysis, structural dynamics, isolation and damping, shock testing, vibration test criteria, modal test and analysis and vibration analysis and test. The instrumentation session contained papers on accelerometer evaluation, random vibration data, and sensor layouts. In the area of shock analysis, papers on testing of plates, panels, and structures were presented. Results of an analysis of shock loading of a vessel by an underwater explosion were compared to a full scale test. In the area of structural dynamics, two sessions were held. Papers on analyses of reinforced concrete structures under blast and shock analysis were presented. Other papers were concerned with optimum design, model validation, reliability, frequency response functions of nonlinear structures, and in interactive-graphics method for dynamic system modeling.

A session on isolation and damping included papers on liquid spring design and applications, a free decay damping test and design and test of a spacecraft instrument shock isolator. In the area of shock testing, a basic study on impact was reported along with rocket sled tests, pyrotechnic shock measurements and data analysis, and a microcomputer used in shock testing.

Papers on vibration test criteria included papers on dynamic environments, the development of laboratory vibration test schedules, and proposed techniques for ground vehicle packaged loose cargo vibration simulation. In the area of modal testing and analysis, a paper on vibration of structures through modal testing coupled with component mode synthesis was given. Papers on hardware modal tests with analytical validation were presented. Finally an approach for modal testing using multiple input sine excitations was

given. A session on vibration analysis and test contained papers on vibration specifications for acoustic environments, fatigue effects of a sine sweep test, flow excitation in piping systems, analysis of clipped random signals, rotor unbalance, and three dimensional sine testing.

Conclusion

The fifty-seventh Shock and Vibration Symposium was both technically informative and interesting yielding a large number of excellent papers. Again the opening and plenary sessions with their overviews and philosophical insights added incomprehensible value to the meeting for new and experienced engineers. The workshop on nondevelopment items was a successful addition to the program yielding insight and experience

for those who participated. The Shock and Vibration Symposium remains the major annual event in the field. Even as it was on its last days SVIC can be congratulated for their continued maintenance of the quality of the technical presentations. It is hoped that this important

forum for the discussion of shock and vibration technology will be continued. The Symposium papers will be published in the 57th Shock and Vibration Bulletin.

R.L.E.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS.....	34		
Rotating Machines.....	34	Beams.....	54
Reciprocating Machines.....	38	Plates.....	55
Power Transmission Systems.....	38	Shells.....	59
Metal Working and Forming.....	38	Pipes and Tubes.....	60
STRUCTURAL SYSTEMS.....	39	Ducts.....	61
Buildings.....	39	Building Components.....	61
Towers.....	40		
Foundations.....	40		
Harbors and Dams.....	40		
Construction Equipment.....	41	ELECTRIC COMPONENTS.....	62
Power Plants.....	41	Electronic Components.....	62
Off-shore Structures.....	41		
VEHICLE SYSTEMS.....	42	DYNAMIC ENVIRONMENT.....	63
Ground Vehicles.....	42	Acoustic Excitation.....	63
Ships.....	43	Shock Excitation.....	65
Aircraft.....	43	Vibration Excitation.....	66
Missiles and Spacecraft.....	45		
BIOLOGICAL SYSTEMS.....	47	MECHANICAL PROPERTIES.....	66
Human.....	47	Damping.....	66
MECHANICAL COMPONENTS.....	47	Fatigue.....	67
Absorbers and Isolators.....	47	Wave Propagation.....	67
Springs.....	50		
Tires and Wheels.....	50	EXPERIMENTATION.....	68
Blades.....	51	Measurement and Analysis.....	68
Bearings.....	51	Dynamic Tests.....	81
Gears.....	52	Scaling and Modeling.....	86
Fasteners.....	53	Diagnostics.....	86
Seals.....	53	Balancing.....	86
STRUCTURAL COMPONENTS.....	54	Monitoring.....	88
Cables.....	54		
		ANALYSIS AND DESIGN.....	89
		Analytical Methods.....	89
		Numerical Methods.....	89
		Parameter Identification.....	89
		Computer Programs.....	90
		GENERAL TOPICS.....	90
		Useful Applications.....	90

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

Institution of Mechanical Engineers publications are available in U.S.: SAE Customer Service, Dept. 676, 400 Commonwealth Drive, Warrendale, PA 15096, by quoting the SAE-MEP number.

When ordering, the pertinent order number should always be included, not the DIGEST abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

86-2369

Random Vibration of Rotating Machines Under Earthquake Excitation

KiBong D. Kim

George Washington Univ., Washington, DC
351 pp (1986) DA8604768

KEY WORDS: Rotating machinery, Seismic response, Random vibration

Random vibration of rotating machines subjected to seismic excitations is analyzed in which the six-component earthquake ground motions are modeled as nonstationary random processes. The six-component earthquake inputs, including the rotational components of base excitations, result in not only nonhomogeneous excitations but also parametric excitations -- the classical spectral analysis of random vibration is not applicable. The method of Monte Carlo simulation is used to simulate sample functions of six-component seismic base motions, and a step-by-step numerical integration is performed to obtain the dynamic response of the rotorbearing system. By simulating sufficient number of sample function, meaningful statistics of the system response are obtained. The random parametric excitations result from the three-component earthquake base rotations. Hence, by neglecting the earthquake ground rotations the spectral analysis of random vibration is performed to determine the system response statistics. The results of the spectral analysis serve as a basis for determining the number of sample functions required for the method of Monte Carlo simulation.

86-2370

Dynamic Analysis of Large Rotor — Fluid Film Bearing — Elastic Foundation Systems Using Component Mode Synthesis

Zhao-chang Zheng, Kui-yuan Ding, Ruo-jing Zhang

Tsinghua Univ., Peking, China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1540-1546, 5 figs, 2 tables, 8 refs

KEY WORDS: Experimental modal analysis, Rotors, Fluid-film bearings, Elastic foundations, Component mode synthesis

A method of component mode synthesis used in the dynamic analysis of rotorbearing foundation

systems is presented. In contrast to the classical method of component mode synthesis, the fluid-film bearing is treated separately as a connector, not associated with any substructures. The gyroscopic terms are neglected in the rotating substructures. Because of the influence of the fluid-film bearings, the stiffness matrix and the damping matrix in the equations of motion of a complete system are nonsymmetric and dependent on the shaft speed. The damped and undamped critical speeds are discussed. As a numerical example, the undamped critical speeds of a (1:10) model of a 300MW turbogenerator are calculated and compared with the experimental results.

86-2371

The Dynamic Analysis of Rotor-Bearing Systems Using Experimental Bearing Support Compliance Data

L.E. Barrett, J.C. Nicholas, D. Dhar

Univ. of Virginia, Charlottesville, VA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1531-1535, 6 figs, 16 refs

KEY WORDS: Experimental modal analysis, Rotors, Steam turbines, Stiffness coefficients, Damping coefficients

The results of computer analyses of the response of an industrial steam turbine to unbalance excitation are described. To account for the flexibility of the bearing supports, compliance FRF data were experimentally obtained by impact testing during customer acceptance tests. The FRF data was used to modify the calculated tilting pad bearing stiffness and damping coefficients. The modified bearing coefficients were used in a response analysis program. Comparison of the calculated rotor response to vibration data measured during acceptance test runs are presented and the method used to modify the bearing stiffness and damping coefficients is presented. This method may be easily incorporated into forced response rotordynamics programs that do not include effects of support structures.

86-2372

On Transient Dynamics of Rotors with Asymmetric Cross-Section Supported on Fluid Film Bearings

J.S. Rao, K.V. Bhaskara

Embassy of India, Washington, DC

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1110-1116, 7 figs, 12 refs

KEY WORDS: Rotors, Fluid-film bearings, Experimental modal analysis

Power plant turbogenerator rotors are asymmetric in cross-section having unequal stiffnesses causing parametric instabilities. A Jeffcott rotor model of the generator taking into account the asymmetry and modal damping is considered to obtain the transient orbital analysis of rotors at different speeds. Fluid film bearings with linear parameters (eight coefficients) are considered. The coupled differential equations of motion with variable coefficients are solved by a modified Euler's method using a time marching technique to obtain the whirl orbits of an asymmetric rotor taking into account both unbalance and gravity effects. Under stable operating conditions the final orbit is shown to be in good agreement with the closed form solution. A major feature of this analysis is to predict the possible maximum whirl amplitudes under unstable conditions of operation. The influence of linear fluid film bearings on the orbital motion is also discussed.

86-2373

Determination of Modal Parameters of Rotors Supported on Hydrodynamic Bearings through Experimental Modal Analysis

R. Subbiah, R.B. Bhat, T.S. Sankar

Concordia Univ., Montreal, Quebec, Canada

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1450-1456, 11 figs, 5 tables, 6 refs

KEY WORDS: Experimental modal analysis, Rotors, Fluid-film bearings

Modal parameters of a single disk rotor, supported on hydrodynamic bearings at the two ends, are identified by modal testing. The experimentally measured frequency response functions of the rotor are used to extract the left and the right eigenvectors in addition to the eigenvalues and damping ratios, in order to construct the modal model of such a nonsymmetrical system. Two different configurations of the rotor system are studied and the natural frequencies obtained by modal analysis are compared with those obtained by the extraction techniques.

86-2374

Vibrations of Rotors, Noise of Measurement, Circularity and Coaxiality

R. Bigret

Materiaux et de la Construction, Mecanique, France

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1388-1392, 15 figs, 2 refs

KEY WORDS: Experimental modal analysis, Rotors, Vibration measurement, Error analysis, Critical speeds

Defects of circularity and coaxiality, noises of electric, and magnetic origin influence the measurements which express the vibratory behaviors of rotors of rotating machinery. Their supervision, balancing, behavior, and modal analysis require that the basic signals rough data be clarified to facilitate the interpretations. Examples are given which show results for the determination of critical speeds (maximum values of the vibration amplitudes) and the modal analysis (transient state). Systems which enable the management of measured signals are also studied.

86-2375

Predicted Effect of Aerodynamic Detuning on Coupled Bending-Torsion Unstalled Supersonic Flutter

D. Hoyniak, S. Fleeter

NASA Lewis Res. Ctr., Cleveland, OH

Rept. No. NASA-TM-87240, 30 pp (1986) (31st Intl. Gas Turbine Conf., Dusseldorf, W. Germany, June 8-12, 1986, spon. by ASME) N86-21513/4/GAR

KEY WORDS: Turbomachinery, Flutter, Aerodynamic stability, Tuning

A mathematical model is developed to predict the enhanced coupled bending-torsion unstalled supersonic flutter stability due to alternate circumferential spacing aerodynamic detuning of a turbomachine rotor. The translational and torsional unsteady aerodynamic coefficients are developed in terms of influence coefficients, with the coupled bending-torsion stability analysis developed by considering the coupled equations of motion together with the unsteady aerodynamic loading. The effect of this aerodynamic detuning on coupled bending-torsion unstalled supersonic flutter as well as the verification of the modeling are then demonstrated by considering an unstable 12 bladed rotor, with Verdon's uniformly spaced Cascade B flow geometry as a baseline. For both uniform and nonuniform circumferentially space rotors, a single-degree-of-freedom torsion mode analysis was shown to be appropriate for values of the bending-torsion natural frequency ratio lower than 0.6 and higher than 1.2. When the elastic axis and center of gravity are not coincident, the effect of detuning

on cascade stability was found to be very sensitive to the location of the center of gravity with respect to the elastic axis. In addition, it was determined that when the center of gravity was forward of an elastic axis location at midchord, a single-degree-of-freedom torsion model did not accurately predict cascade stability.

86-2376

Internal Resonance in a Rotating Shaft System (The Coincidence of Two Critical Speeds for Subharmonic Oscillation of the Order 1/2 and Synchronous Backward Precession)

Yukio Ishida, Takashi Ikeda, Toshio Yamamoto, Tetsuyoshi Akita
Nagoya Univ., Chikusaku, Nagoya-city, Japan
Bull. JSME, 29 (251), pp 1564-1571 (May 1986) 7 figs, 16 refs

KEY WORDS: Shafts, Critical speeds, Subharmonic oscillations, Internal resonance

Vibration phenomena due to an internal resonance in a symmetrical rotating shaft system with nonlinear spring characteristics is discussed. The coincidence of critical speeds of subharmonic oscillation of the order 1/2 and synchronous backward precession is investigated. It is revealed that these oscillations are coupled by nonlinear components expressed by polar coordinates and that unique shapes of resonance curves appear due to internal resonance.

86-2377

Dynamic Stress Analysis of Hollow Rotating Discs

S. Amada
Ship Res. Institute, Tokyo, Japan
Bull. JSME, 29 (251), pp 1381-1395 (May 1986)
12 figs, 3 tables, 11 refs

KEY WORDS: Disks, Shafts, Rotating structures

Dynamic radial and circumferential stresses are analyzed for hollow rotating disks which rotate at arbitrarily varying speeds, the inner boundary of which is fixed on a rigid shaft. The problem is solved by using the Laplace transform, the convolution and Cauchy's integral theorems. The numerical computations are carried out for the disks which rotate with a constant angular acceleration up to $N=10,000$ rpm, and keep their rotation thereafter. The dynamic stresses give rise to the cyclic variations with respect to time in a constant rotating process. The obtained results are compared with the quasi-static stresses.

86-2378

Types of Rotors Fit and the Gyroscopic Moments Effect on Multi Disc Rotor Supported on Several Bearing

E.M. Badawy, H.M. Metwally, F.K. Salman
Alexandria Univ., Alexandria, Egypt
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1382-1387, 6 figs, 10 refs

KEY WORDS: Shafts, Whirling, Supports, Damping effects

A calculation method incorporating the transfer matrix method and the characteristic vector locus method has been developed for stability analysis of the self-excited vibration of a rotating shaft system with many bearings and disks. The analysis is made for a rigid and elastic bearing mass, relatively large damping forces due to types of rotors fit, anisotropic foundation and rotors gyroscopic effect. A two rotors-model is presented to show the influence of rotor and its gyroscopic action, support stiffness characteristic, internal and external damping on stability. A computer solution of the transfer matrix method shows the rotor stability improved by damped support. Comparison of the rotor types fit, support types and its gyroscopic action are obtained.

86-2379

Modal Testing and Parameter Identification of Rotating Shaft/Fluid Lubricated Bearing System

D.E. Bentley, A. Muszynska
Bently Rotor Dynamics Research Corp., Minden, NV
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1393-1402, 15 figs, 34 refs

KEY WORDS: Shafts, Fluid-film bearings, Experimental modal analysis, Parameter identification technique

Specific aspects of the application of modal analysis to rotating machines are discussed. For lowest mode analysis, the circular-force perturbation testing and dynamic stiffness method give the best results. An example of the application is presented. It yields identified parameters for the whirl mode (solid/fluid interaction mode) and whip mode (first bending mode of the shaft) and establishes a simple rotor/bearing system model.

86-2380

Modifications to a Timoshenko Beam-Shaft Finite Element to Include Internal Disks and Changes in Cross-Section

S. Akella, A. Craggs

Univ. of Alberta, Edmonton, Alberta, Canada
J. Sound Vib., 106 (2), pp 227-239 (Apr 22, 1986) 14 figs, 2 tables, 17 refs

KEY WORDS: Shafts, Beams, Timoshenko, Finite element technique

A high order Timoshenko beam-shaft element is modified to include the effect as disks within its length. The method leads to a great reduction in the system matrix, without loss of accuracy of the results when compared to the classical method of lumping the disks at nodal points. A stepped element is also formulated which includes the variation in inertia and stiffness terms due to the changes in the cross-section of an axially discontinuous shaft. The stepped element performs better than the linearly tapered element in representing shaft discontinuities.

86-2381

Damping of Subsynchronous Resonance Using a Load Commutated Inverter Synchronous Motor Drive

Soebagio

Ph.D. Thesis, Univ. of Wisconsin, Madison, WI, 165 pp (1985) DA8601124

KEY WORDS: Shafts, Subsynchronous vibration, Damping effect, Resonant response

Subsynchronous resonance (SSR) has been considered a serious problem since 1970 when incidents of severe generator shaft damage occurred at a generating station in southern Nevada. This problem is caused by inserting a series capacitor in transmission lines for the purpose of raising line capacity to transmit very huge amounts of power over long distances. The installation of the series capacitor in the lines may cause oscillation due to the light damping in the electrical or mechanical system. If there is a small perturbation in the accelerating torque of the generator, this perturbation will introduce negative damping to the mechanical system, so that the system becomes unstable. This research proposes a method using a load commutated inverter (LCI) synchronous motor drive. The advantage of the proposed method is that an inductor converter unit is used which is already available as part of a LCI synchronous motor drive to operate a variable speed induced fan or compressor for cooling purposes.

86-2382

Sensor for Torque Measuring on the Basis of Amorphous Metals (Sensor zur Drehmomentmessung mit amorphen Metallen)

D. Juckenack, J. Molnar

Fraunhofer-Institut, Friburg, Fed. Rep. Germany
Techn. Messen-TM, 53 (6), pp 242-248 (June 1986) 13 figs, 18 refs (in German)

KEY WORDS: Shafts, Torque, Measurement techniques

With the help of amorphous metals mounted on a rotating shaft and a coil system fixed in a housing, the static and dynamic torque is detected without any signal transmission parts and with good sensitivity.

86-2383

Response of a Rigid Disc Mounted on a Flexible Shaft Under Non-Linear Excitations

V. Steffen, Jr., F.P. Lepore N., E.B. Teodoro
Fed. Univ. of Uberlandia, Uberlandia, Brazil
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1536-1539, 6 figs, 1 table, 7 refs

KEY WORDS: Experimental modal analysis, Disks, Flexible shafts, Ball bearings

A mathematical model of a rigid disk mounted on a flexible shaft supported by ball bearings is presented. The disk is excited by a magnetic force. The equations of motion are integrated using a Runge-Kutta technique and the frequency response is obtained by an FFT technique. The response of the system is discussed for different situations.

86-2384

Coupled Bending Vibrational Characteristics of an Idealized Vertical Pump Model

Jang Moo Lee, Chan-Gi Pak, Jin Sun Hong
Seoul National Univ., Seoul, Korea
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 877-883, 12 figs, 7 tables, 10 refs

KEY WORDS: Pumps, Rigid foundations, Flexural vibrations, Experimental modal analysis

Coupled bending vibrational characteristics of a vertical pump due to foundation stiffness are investigated through the vibration analysis of an idealized vertical pump model. The model assumes the upper motor casing and the lower water lifting pipe as uniform beams, the motor and the pump impeller as concentrated masses, the discharging pipe as a translational spring and the foundation stiffness as a rotational spring. The equations of motion corresponding to each portion of the pump are solved simultaneously with the matching boundary conditions. The

eigenvalues and eigenvectors are computed as dimensionless design variables and the effects of foundations stiffness are discussed. The validity of the analysis results is checked through comparison with the results of previous studies and impulse modal testing.

RECIPROCATING MACHINES

86-2385

Effect of Entrained Air on Dynamic Characteristics of Hydraulic Servosystem with Asymmetric Linear Motor

B.N. Datta, A.S.R. Murty, G.L. Sinha
B.E. College, Howrah, India
Mecchanica, 21 (1), pp 51-57 (Mar 1986) 7 figs, 6 refs

KEY WORDS: Hydraulic systems, Servomechanisms, Stiffness coefficients, Damping coefficients, Natural frequencies

A theoretical investigation into the effect of entrained air on dynamic behavior of a hydraulic servosystem is made. The nonlinear system equation developed in dimensionless form is linearized to obtain stiffness, damping ratio and natural frequency in generalized dimensionless form that includes the effects of underlap, leakage, area ratio, per cent air content and the process of change of state of air. A nomogram is developed that helps in quick determination of the dynamic properties directly without any computation. The analysis shows that a decrease in area ratio or an increase in the amount of air entrained into the system reduces both damping ratio and natural frequency.

POWER TRANSMISSION SYSTEMS

86-2386

A Study on Forced Torsional Vibration of Automobile Power Train

Wang Zhiun, Wu Huile
Shanghai Univ. of Engng. Science, Shanghai, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 972-978, 5 figs, 2 tables, 6 refs

KEY WORDS: Driveline vibrations, Automobiles, Torsional vibrations

A theoretical study based on the forced vibration theory and a new complete experimental method are used to reveal the torsional vibration behav-

ior of an automobile power train. A dynamic model is developed for CA-630 coach power train, the parameters of the system are determined, an experimental investigation is made, and results are presented.

86-2387

Modal Analysis for Bending Vibration of Vehicle Power Trains

Wu Huile, Feng Zhendong, Li Chengde, Sun Fangning
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 965-971, 6 figs, 3 tables, 3 refs

KEY WORDS: Experimental modal analysis, Modal synthesis, Flexural vibrations, Driveline vibrations, Buses

A method of combining testing modal analysis with modal synthesis techniques is used to investigate the bending vibration of a vehicle's power trains. The mechanical and mathematical model for bending vibration of a DD680 bus power train are developed and the natural vibration property is calculated. A test is made to check the validity of the model.

METAL WORKING AND FORMING

86-2388

Using Frequency Response Function Measurements to Predict Workpiece Noise Radiation during Face Milling

T. Moore, Jimi Sauw-Yoeng Tjiong, Z. Reif
Queen's Univ., Kingston, Ontario, Canada
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 930-935, 9 figs, 11 refs

KEY WORDS: Milling (machining), Noise prediction, Frequency response functions

A simple method is described which predicts the spectral characteristics of the noise generated by a workpiece of complex geometry while one of its surfaces is being face milled. Such information can be used to design quiet cutters; i.e., mills which produce a minimum of noise during a given cutting cycle. The method consists of the generation of frequency response functions with the input being force and the output being sound pressure. Such measurements provide a direct link between input force and the resulting noise generation, thus measurements require no simplifying assumptions to link surface movement to resulting sound pressure at a point in space.

If the measurements are made with the work-piece mounted in its machining fixture, the results automatically include the complex boundary conditions imposed on the workpiece.

86-2389

Computer Aided Milling Machine Modal Analysis

Hsin-Yi Lai

North Carolina A&T State Univ., Greensboro, NC
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1140-1148, 9 figs, 1 table, 16 refs

KEY WORDS: Machine tools, Milling (machinery), Modal analysis, Time domain method, Computer programs

A time-domain modal analysis method with application to the identification of a milling machine structure is presented. In a systematic modeling procedure, the model structure and the related parameters of each dynamic mode are identified in sequence. The relative vibration amplitudes are displayed in terms of animated mode shapes. The constructural weak points are pinpointed and the model refinement is made based on the modification of physical means. Results, as compared with those of finite element and fast fourier transformation approaches, show the time-domain modal analysis method possesses the advantages of practicality and accuracy in dynamic data processing. It can be used as a powerful structure analysis tool, vital for various CAD/CAM applications including dynamic verification, model developed and design refinement of components in flexible manufacturing cells.

86-2390

The Static and Dynamic Analyses of Machine Tools Using Dynamic Matrix Reduction Technique

V.R. Reddy, A.M. Sharan

Memorial Univ. of Newfoundland, St. John's, Newfoundland, Canada

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1104-1109, 1 fig, 2 tables, 8 refs

KEY WORDS: Machine tools, Matrix reduction methods, Experimental modal analysis

An approach, for condensing the system matrices of machine-tool structures, based on dynamic condensation, is presented. The selection of the number of degrees-of-freedom to be retained in the condensed system is based on the accurate representation of the first five modes of the original system. This is illustrated by an example of a lathe spindle-workpiece system.

86-2391

Evaluation of Optimum Stiffness and Damping for Structural Design of Machine Tools

M. Rahman, V. Narayanan, V.C. Venkatesh
National Univ. of Singapore, Kent Ridge, Singapore

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1553-1557, 9 figs, 9 refs

KEY WORDS: Machine tools, Stiffness coefficients, Damping coefficients, Optimization, Structural modification techniques

An attempt is made to optimize stiffness and damping for the structural design of machine tools. These factors were tried on a widely used stability theory based on a feedback control system. Actual machining tests were carried out varying these factors. Calculated stability prediction has been found to agree qualitatively with the experimental values.

STRUCTURAL SYSTEMS

BUILDINGS

86-2392

Sound Transmission by Coupled Structures: Application to Flanking Transmission in Buildings

J.L. Guyader, C. Boisson, C. Lesueur, P. Millot
Institut National des Sciences Appliquees, Cedex, France

J. Sound Vib., 106 (2), pp 289-310 (Apr 22, 1986) 12 figs, 17 refs

KEY WORDS: Buildings, Sound transmission

A new formulation for sound transmission by coupled structures with special application to flanking transmission is presented. As distinct from other approaches in which the couplings are considered to be similar, this method treated each type of coupling specifically: the mechanical/mechanical coupling is rigorously treated; the mechanical/acoustic coupling is considered to be weak, this hypothesis being generally admissible when air is the acoustic medium fluid. The formulation proceeds from the general to the specific; in this way it is easier to measure the effect of the hypothesis introduced. The theoretical procedure for defining the transmissions leads to an experimental method in which measured data of the energy and spectral densities of the forces is used. The application of

this method to the case of sound transmission in buildings was carried out to serve as an example.

TOWERS

86-2393

Wind Loads on Windmills at Stand Still

O. Christensen

Risoe National Lab., Roskilde, Denmark

Rept No. RISO-M-2521, 60 pp (Jul 1985)
DE86751137/GAR (in Danish)

KEY WORDS: Towers, Wind turbines, Wind-induced excitation

The report deals with calculation of static and dynamic wind loads on windmills at stopped condition, including induced vibrations in the construction. The assumptions for the calculations are a total stiff tower, a three-bladed rotor and that the wind is at right angles to the rotor plane.

FOUNDATIONS

86-2394

Dynamic Soil-Structure Analysis by Boundary Element Method

M.H.M. Abdalla

Ph.D. Carleton Univ., Canada (1985)

KEY WORDS: Soil-structure interaction, Seismic response, Boundary element technique

A method is developed to analyze the earthquake response of a two-dimensional soil-structure system. The semi-infinite soil domain is modeled by boundary elements, while the structure is modeled as an assemblage of finite elements. A substructure technique of analysis is used and the soil material as well as the superstructure material are considered homogeneous, isotropic and linearly elastic. The analysis is carried out by first resolving the earthquake excitation into a series of harmonic components. The steady state response of the system to each harmonic component is obtained next. The component response is then Fourier synthesized to obtain the resultant response in time domain. The Fourier analysis is accomplished by using Fast Fourier Transform method.

HARBORS AND DAMS

86-2395

On Phase and Modal Parameter Measurement for Large Structures

Zhong Liang, Qiang Gao, D.J. Inman

State Univ. of New York, Buffalo, NY

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 993-999, 3 figs, 5 refs

KEY WORDS: Dams, Parameter identification technique, Mode shapes, Phase methods, Time domain method

The identification of modal parameters for a large structure, such as a dam, is plagued with unusual difficulties. In particular, excitation, phase angle measurement (between two measuring points) and the need to consider a large number of degrees-of-freedom complicate the process. Based on the stochastic process of microvibration, excited by water waves or a seismic tremor, formulas for the phase angle and three cross-correlation functions between two measuring points are developed. Phase measurement is important for developing a new method of identifying complex modes and providing a determination of natural frequencies. A time domain method is used to determine the complex mode shapes, natural frequencies and the damping ratios accurately and quickly.

86-2396

Modal Analysis of Inflatable Dams under Hydrodynamic Conditions

A.D. Alwan

Univ. of Basrah, Basrah, Iraq

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1502-1509, 16 figs, 7 refs

KEY WORDS: Experimental modal analysis, Dams, Inflatable structures, Finite element technique

An inflatable dam consisting of a single sheet of rubberized fabric folded into a tubular shaped bag which is then sealed into place during installation is investigated. The bag is fixed at the base and inflated by air, water or a combination of both. A numerical model based on the finite element approach to analyze the dam under hydrodynamic conditions is presented. The forces acting on the dam due to variation of overflow head, downstream head, and inflated pressure are analyzed to study the behavior and performance of the dam and to find the shape of the profile of the dam and the tension of the fabric.

CONSTRUCTION EQUIPMENT

86-2397

Modelling of the Dynamic Processes of Excavator

Zhang Hui Jiao, Fang Dan Ping

Shanghai Jiao Tong Univ., China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1215-1219, 9 figs, 2 tables, 3 refs

KEY WORDS: Excavators, Modal analysis

A new method combining theoretical analysis with practical measured data is developed for modeling the dynamic processes of excavators. Using this method, a realistic model and a high accuracy load spectrum can be established.

Equipment in operating nuclear power plants cannot be qualified in a practical manner by analysis or testing alone. This paper addresses new procedures in combined methods of testing and analysis which enable an estimate of modal participation factors to be developed without recourse to a conventional mass survey. The procedures generate the required response spectra for instruments or devices mounted at elevated positions in equipment or structures using in-situ measured modal parameters and postulated base excitations as inputs. Examples are given to demonstrate the ability of the procedures to develop the parameters of modal participation factors necessary to predict the elevated response spectra.

POWER PLANTS

86-2398

Seismic and Dynamic Qualification of Safety Related Electrical and Mechanical Equipment

M. Subudhi, J. Curreri, M. Reich

Brookhaven National Lab., Upton, NY

Rept. No. BNL-NUREG-51643, 66 pp (Mar 1986)
NUREG/CR-3137/GAR

KEY WORDS: Nuclear power plants, Nuclear reactor components, Seismic tests

The report presents a summary of methods and procedures that may be used for seismic qualifications of nuclear power plant mechanical and electrical equipment. Incorporated into text are sections that explain and clarify commonly used qualification terminology and that delineate methods used for dynamic environment simulations used for qualification. The report also presents a scenario of what occurs at a typical seismic qualification review team audit of a NTOL nuclear power station.

86-2399

A Combined Method of Testing and Analysis for Dynamic Qualification of Equipment

K.Y. Shye, K.M. Skreiner

NUTECH Engineers, San Jose, CA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1370-1373, 1 fig, 2 tables, 4 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test, Nuclear power plants, Nuclear reactors

OFF-SHORE STRUCTURES

86-2400

The Mechanics of a Compliant Motion Suppression System for Semisubmersibles

M.H. Patel, J.H. Harrison

Univ. College, London, England

J. Sound Vib., 106 (3), pp 491-507 (May 8, 1986)
13 figs, 11 refs

KEY WORDS: Submerged structures, Offshore structures, Drilling platforms, Wave forces, Vibration control

Experimental and theoretical work on a passive motion suppression system for semisubmersible vessels are described. The system incorporates a pneumatic compliancy which is designed to enhance the wave induced motion characteristics of such a vessel for offshore drilling and production service. The pneumatic compliancy is achieved through the use of open bottom tanks mounted on the vessel. Test data is compared with a multi-degree-of-freedom dynamic response calculation in the frequency domain in which the Morison equation is used for calculating wave induced drag and inertia loads on the semisubmersible. The paper is concluded with a discussion on the relative merits and drawbacks of incorporating a pneumatic compliancy into hitherto hydrodynamically rigid semisubmersible designs.

86-2401

Decomposition of Wave Forces into Linear and Non-Linear Components

J.S. Bendat, A.G. Piersol

J.S. Bendat Co., Los Angeles, CA

J. Sound Vib., 106 (3), pp 391-408 (May 8, 1986)
19 figs, 5 refs

KEY WORDS: Off-shore structures, Wave forces

This paper details a methodology for analyzing nonlinear systems involving a square-law operation with sign. The analysis is applied specifically to the problem of decomposing random wave forces on an ocean structure into their inertial (linear) and drag (nonlinear) components. A procedure is presented for identifying the individual inertial and drag force parameters based solely upon measurements of the input wave velocity and the output wave force, where the wave velocity has an arbitrary spectral density function and mean value, and the inertial and drag forces have an arbitrary frequency dependence and phase. It is assumed only that the wave velocity is a Gaussian random process. Experimental verifications of the analysis procedure are presented.

The mode synthesis technique and least squares method are adopted for finding the weak points of a structure. A spectrum of system normal frequencies in the range of interest and their associated mode shapes can be produced with the mode synthesis method. These modes are drawn up by the cubic curves obtained by the least squares method. The deformations of the complex structure are represented by these curves and by which the relative stress values of the system can be calculated. This method provides some advantages, such as mathematical simplicity and computer time saving.

VEHICLE SYSTEMS

GROUND VEHICLES

86-2402

Some Problems About Acoustic and Vibration Comfort in Vehicle Design

A. Garro, E. Pellegrino, V. Vullo
Fiat Auto S.p.A., Turin, Italy

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 957-964, 6 figs, 1 table, 16 refs

KEY WORDS: Modal analysis, Automobile noise, Interior noise

A mathematical model is presented to analyze the acoustics of a small cavity such as the interior of a vehicle. The mathematical fundamentals of the calculation procedure are outlined. This procedure uses discretization methods and allows for acoustic analysis of the cavity in a more general case where it is delimited by partly stiff and partly flexible walls.

86-2403

A Substructure Synthesis Method for Finding the Weak Points of Complex Structure

Wu Jian-ji, Zheng Zhao-chang
Tsinghua Univ., Beijing, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 979-983, 1 fig, 1 table, 4 refs

KEY WORDS: Automobile bodies, Trucks, Modal synthesis, Substructuring methods

86-2404

The Study of Vibration Characteristics of a Whole Truck

Li Tong, Li Cheng De, Yu Hui Ran
Changchun Automobile Research Institute, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1640-1652, 19 figs, 10 tables, 4 refs

KEY WORDS: Trucks, Modal analysis, Finite element technique, Modal synthesis, Design techniques

Using modal analysis theories, the dynamic finite element method, and the modal synthetic technique, a mathematical model of a whole truck has been established. This model includes the modal coordinates and independent coordinates of frame, engine, radiator, cab, front and rear axles, cargo body, etc. -- all main components of a truck. Using finite element and modal truncation theories, this model having 33 degrees-of-freedom, realistically describes the complicated system of a whole truck. Dynamic calculations are carried out on a computer.

86-2405

Modal Analysis as a Tool to Evaluate Off-Road Vehicle Body Mounts

S. Sankar, S. Rakheja, J. Alanoly
Concordia Univ., Montreal, Quebec, Canada
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1471-1475, 8 figs, 1 table, 7 refs

KEY WORDS: Experimental modal analysis, Off-highway vehicles, Mounts, Finite element technique, Road roughness

A four wheel drive off-road vehicle with a combination of rigid and flexible mounts between the chassis and body shell is considered to study the deflection behavior of the body. The deflection modes of the body chassis structure are

obtained through analytical and experimental modal analyses. The analytical results obtained through finite element modeling show good agreement with experimental results. Based on deflection behavior of the body shell, conclusions on location of rigid and flexible connections are drawn to improve the integrity of body shell structure.

SHIPS

86-2406

The Identification of System Modal Parameters of the Ship Hull Girder Vibrating in Its Vertical Plane by the Sea Trial Time Series

Chang-Sheng Li, Wen-Jiunn Ko
National Taiwan Univ., Taipei, Taiwan, Rep. China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1011-1019, 17 figs, 7 tables, 11 refs

KEY WORDS: Ship hulls, Parameter identification technique, Experimental modal analysis, Experimental data, Autoregressive/moving average models

In the sea trial for a newly constructed tanker, under prescribed loading conditions, six sets of pick-up devices were distributively mounted on the main deck of the ship along its longitudinal direction. The analog signals of structural responses or the time history of dynamic response of the ship hull box girder were recorded on a multi-channel tape recorder simultaneously, while the ship was sailing on calm seas. The recorded data was processed using a band-pass filter and A/D converter. With these data, a time series analysis was conducted by the autoregressive moving average model, from which the modal frequencies can easily be identified according to the index of energy dispersion.

AIRCRAFT

86-2407

STEP and STEPSPL: Computer Programs for Aerodynamic Model Structure Determination and Parameter Estimation

J.G. Batterson

NASA Langley Res. Ctr. Hampton, VA
Rept. No. NASA-TM-86410, 142 pp (Jan 1986)
N86-21549/8/GAR

KEY WORDS: Aircraft, Computer programs, Parameter identification technique

The successful parametric modeling of the aerodynamics for an airplane operating at high angles of attack or sideslip is performed in two phases. First the aerodynamic model structure must be determined and second the associated aerodynamic parameters (stability and control derivatives) must be esitmated for that model. The purpose of this paper is to document two versions of a stepwise regression computer program which were developed for the determination of airplane aerodynamic model structure and to provide two examples of their use on computer generated data. References are provided for the application of the programs to real flight data. The two computer programs that are the subject of this report, STEP and STEPSPL, are written in FORTRAN IV (ANSI 1966) compatible with a CDC FTN4 compiler. Both programs are adaptations of a standard forward stepwise regression algorithm.

86-2408

The Planning of an Environmental Testing Program for an Externally Carried Store

Z. Sherf, A. Gilan, P. Hopstone, R. Klein
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 20-25, 11 figs, 29 refs

KEY WORDS: Aircraft wings, Wing stores, Vibration tests

The planning of a vibration and temperature testing program for an external airborne store is summarized. In the absence of field measurements for the test item, use is made of measured data for similar systems of empirical models and of laboratory acquired data. Tailoring of the testing conditions is performed with respect to the mission profile of the system.

86-2409

Equivalent Plate Analysis of Aircraft Wing Box Structures with General Planform Geometry

G.L. Giles

NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-87697, 12 pp (Mar 1986)
(Pres. at 27th AIAA/ASME/ASCE/ANS Structures, Structural Dynamics & Matrls. Conf., San Antonio, TX, May 19-21, 1986) N86-21954/0/GAR

KEY WORDS: Aircraft wings, Equivalent plate analysis method

A new equivalent plate analysis formulation is described which is capable of modeling aircraft wing structures with a general planform such as

cranked wing boxes. Multiple trapezoidal segments are used to represent such planforms. A Ritz solution technique is used in conjunction with global displacement functions which encompass all the segments. This Ritz solution procedure is implemented efficiently into a computer program so that it can be used by rigorous optimization algorithms for application in early preliminary design. A direct method to interface this structural analysis procedure with aerodynamic programs for use in aeroelastic calculations is described. This equivalent plate analysis procedure is used to calculate the static deflections and stresses and vibration frequencies and modes of an example wing configuration. The numerical results are compared with results from a finite element model of the same configuration to illustrate typical levels of accuracy and computation times resulting from use of this procedure.

86-2410

Noise Transmission into Enclosures

R. Vaicaitis, D.A. Bofilius

Columbia Univ., New York, NY

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1088-1097, 9 figs, 41 refs

KEY WORDS: Enclosures, Noise transmission, Aircraft noise, Interior noise, Experimental modal analysis

Analytical and experimental studies of noise transmission into rectangular and cylindrical enclosures is described. The solutions of the governing acoustic-structural equations are developed by modal decomposition of structural vibrations and the interior acoustic field. Particular attention is directed toward the low frequencies; that is, frequencies up through the first few structural and cavity resonant modes. The structural vibrations are driven by the external acoustic and/or mechanical point loads which are taken to be Gaussian stationary random processes. The structural models include rectangular panels and cylindrical shells.

86-2411

The Methods Implemented at ONERA to Improve Airplane Ground Vibration Tests

R. Dat, P. Lubrina

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 844-849, 5 figs, 15 refs

KEY WORDS: Experimental modal analysis, Aircraft vibration, Vibration tests, Testing techniques

The Office National d'Etudes et de Recherches Aerospatiales (ONERA) has at its disposal full instrumentation and computing equipment installed in a trailer-truck to perform ground vibration tests of aircraft prototypes. The tests must be carried out in a relatively short time and the test results (eigenfrequencies, damping, mode shapes, and generalized masses) must be accurate enough to make aeroelastic analyses reliable. In order to meet those requirement, ONERA has implemented a computation code, which is currently used to analyze frequency responses, and several testing methods which are used when nonlinear structural characteristics make the structural identification difficult.

86-2412

Measurement of Noise from Airplanes Traveling at Heights 3500 to 6000M

M. Linde, S. Meijer

Aeronautical Res. Inst. of Sweden, Stockholm

Rept. No. FFA-T1-AU-2168, 19 pp (Sep 1985)
N86-22312/0/GAR

KEY WORDS: Aircraft noise, Noise measurement

The noise on the ground produced by overflights of jet and propeller airplanes, at different flight levels, was studied to provide a basis for the estimation of the noise from future propeller airplanes. The noise on the ground from airplanes at heights 3500 to 6000m was measured.

86-2413

Contribution to the Digital Compensation of Periodic Disturbances with Frequencies in Bounded Intervals

R. Froriep

Deutsche Forschungs-und Versuchsanstalt fuer Luft und Raumfahrt e.V., Oberpfaffenhofen, Fed. Rep. Germany

Rept. No. DFVLR-FB-85-55, 141 pp (Sept 1985)
N86-21553/0/GAR (in German)

KEY WORDS: Helicopter vibration, Active vibration control

A general design method for the simplest possible compensator was developed in order to satisfy the requirement of stationary disturbance compensation within given tolerance limits for all helicopter rotor speeds within a given bounded interval. The approach to the suppression of rotor induced vibrations is to suspend the fuselage from the rotor by electrohydraulic actuators. Using a digital computer the most dominant harmonics of the disturbance can be actively compensated. For compensation at

sampling instants, a structure of a digital controller is introduced and motivated, in which a minimal number of parameters is adapted to a varying rotor speed. The remaining parameters are to be held constant during operation independent of rotor speed.

86-2414

Developments in Helicopter Ground Vibration Testing

J.A. Fabunmi

Univ. of Maryland, College Park, MD

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 984-992, 8 figs, 9 refs

KEY WORDS: Helicopter vibration, Vibration tests, Single point excitation technique, Experimental modal analysis, Experimental data

A basic review of existing techniques for helicopter mobility testing is presented along with some recent formulations and techniques for efficient measurement of structural dynamic characteristics of a helicopter during ground vibration testing. For single point shaking, a new method is described for calculating the transfer mobility between excitation and response coordinates which results in substantial saving in testing duration, while assuring acceptable accuracy. Test results using this method are presented and compared with existing methods. The formulation for extending this method to multiple shaker testing is also presented.

MISSILES AND SPACECRAFT

86-2415

Quality of Modal Analysis and Reconstruction of Forcing Functions Based on Measured Output Data

H. Ory, H. Glaser, D. Holzdeppe

Institut fur Leichtbau, Aachen, Fed. Rep. Germany

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 850-857, 9 figs, 9 refs

KEY WORDS: Spacecraft, Modal analysis, Launch vehicles, Forcing function

The accuracy of the flight load prediction for a launch vehicle payload greatly depends on the quality of the mathematical model and the representativity of the used forcing functions. These can be deduced from structural responses (accelerations, stresses, etc.) measured during

prior launches. In this paper some criteria influencing the accuracy of the reconstruction of the transient active load and its time history are analyzed. It is shown by some simple examples that the purpose of the reconstruction, either forces and their distribution or main structural loads only, defines the quality required for the mathematical model of the measured prior spacecraft. The knowledge of the spacecraft stiffness matrix and of some few eigenmodes enables the use of the inverse Williams procedure, which delivers forcing functions precise enough for the strength analysis of the primary structure.

86-2416

Substructure Coupling of Analytical and Test Models for an Experimental Structure

F. Charron, V.K. Jha, H. Lapierre, S.J. Sorocky

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1463-1470, 3 figs, 11 tables, 6 refs

KEY WORDS: Experimental modal analysis, Spacecraft, Substructuring methods

Substructure coupling as a means of synthesizing the structural model for a large structure is demonstrated. An experimental satellite structure consisting of two substructures was built and tested. Substructure experimental and analytical models were generated and coupled by using SYSTAN software. The synthesized results were compared with the NASTRAN and test results of the complete structure. Results showed that modes of the coupled structure sensitive to clamped boundary conditions between substructures were better synthesized by using analytical substructure models, while those sensitive to certain asymmetries in substructure material properties were synthesized by using the test derived model for the substructure.

86-2417

Transient Modal Tuning

G.D. Shepard

Univ. of Lowell, Lowell, MA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1482-1486, 3 figs, 2 tables, 3 refs

KEY WORDS: Experimental modal analysis, Spacecraft, Impulse response, Tuned frequencies

For space structures that are too large and fragile to be dynamically tested on earth, system identification must be conducted in space. The space environment, however, restricts many of

the modal testing techniques normally used on earth. For instance, actuators are too sparse and poorly positioned to efficiently excite structural dynamic modes, and energy limitations favor transient inputs with narrow bandwidths. This report considers the advantages of using the impulse response of a particular complex structural mode as an input to selectively enhance that mode. For this case, the response of the desired single mode increases monotonically relative to the undesired responses.

86-2418

Boundary Integral Equation Approach to Non-linear Response Control of Large Space Structures: Alternating Technique Applied to Multiple Flaws in Three-Dimensional Bodies

P.E. O'Donoghue

Ph.D Thesis, Georgia Institute of Technology, 248 pp (1985) DA8605280

KEY WORDS: Spacecraft, Vibration control, Boundary integral equation method, Plates

The topic of vibration control of large space structures is addressed. This control involves the calculation of forces that must be applied to the structure so as to damp out any excessive motion and to maintain the shape at some desired configuration. In particular the large space structure is idealized by a flat plate where equivalent continuum models are employed to establish the characteristics of such a structure. Both linear and nonlinear systems are controlled. In the linear case the well known linear optimal control principles, using a quadratic performance index, are used to calculate the appropriate feedback control forces. In the nonlinear problem, which is related to the large deformation of a thin flat plate, the controlling forces are designed from the linear portion of the equations and the resulting system is shown to be asymptotically stable.

86-2419

Simulation Efficiency in Acoustic Testing of Shuttle Payloads

F.J. On, E.J. Kirchman

NASA Goddard Space Flight Ctr.

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 202-209, 16 figs, 1 table, 6 refs

KEY WORDS: Acoustic tests, Test facilities, Space shuttles

Based on the results of this study, the assumption that imposing ground acoustic test levels repre-

sentative of the Shuttle cargo bay acoustic environment in the payload will yield a satisfactory (or conservative) test has been found to be invalid.

86-2420

Derivation of Captive Carry Vibration Environment

R.E. Thaller, D. Brown

Wright-Patterson Air Force Base, OH

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 215-223, 20 figs, 4 refs

KEY WORDS: Air launched missiles, Acoustic tests

Designed to withstand a projected 8 hours of B-52 takeoff acoustics, the AGM-86B air launched cruise missile (ALCM) will be exposed to an expected lifetime of 125 hours of more severe boundary layer noise environment during B-1B external carriage. External carriage acoustic estimates exceeded the ALCM design requirements in the 500 Hz octave band and below. Because no analysis techniques or transfer functions existed to convert the input below 200 Hz into vibration response, an ALCM acoustic test was initiated. The test was also an opportunity for a preliminary evaluation of missile endurance.

86-2421

Recent Trends in Acoustic Test Facilities

R.M. Slone, Jr.

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 155-156

KEY WORDS: Test facilities, Acoustic tests, Space shuttles

Special purpose acoustic test facilities are springing-up around the world for system level testing of space flight hardware. These facilities differ very little in size or test capability from their predecessors in the U.S. The refinements in these contemporary acoustic facilities are evolutionary improvements on earlier facilities in the U.S. The nature of these refinements is such as to help promote high intensity acoustic testing to a more repeatable and standardized form of qualifying space flight hardware.

86-2422

System Level Acoustic Test Effectiveness

D.A. Smith

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 148-151, 8 figs

KEY WORDS: Spacecraft, Acoustic tests

This analysis indicated that system level acceptance testing detected 64 potential failures that may have resulted from exposure to the high intensity acoustic dynamic environment for 81 vehicles analyzed. Only one of these potential failures occurred and was detected while monitoring during acoustic testing at the system level. The other 63 were detected during post acoustic functional testing. The one failure was ultimately corrected with a design change. This one failure was not verified during the post acoustic functional since it was a dynamic environment susceptible failure mode only. It was verified during subsequent failure analysis and was determined to have been caused by the deck flutter damper assembly that was an integral part of the tape recorder itself.

BIOLOGICAL SYSTEMS

HUMAN

86-2423

Effects of Helmet Weight and Center-of-Gravity on the Vibratory Dynamics of the Head-Neck System: A Modeling Approach

C.D. Hayes, J.F. Wasserman, B.P. Butler
Univ. of Tennessee, Knoxville, TN
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1201-1207, 3 figs, 2 tables, 9 refs

KEY WORDS: Helmets, Head (anatomy), Mathematical models, Vibration excitation

A four-degree-of-freedom mathematical model was developed to describe the effects of varying helmet weight and center-of-gravity (CG) on the vibration characteristics of the head-neck-helmet system. The model consists of two pivot points connected by a system rotational springs. Experimental data, collected from six subjects exposed to single- and multiple-axis vibration while wearing a variable weight/variable CG helmet, was used to determine rotational spring coefficients. Data from a simplified model was compared to experimental head-neck motion data to illustrate the change in head-neck-helmet motion due to the change in helmet weight and CG.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

86-2424

Design and Testing of Base Isolators

J.M. Kelly
Univ. of California, Berkeley, CA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1305-1311, 9 figs, 3 tables, 5 refs

KEY WORDS: Experimental modal analysis, Base isolation, Elastomers, Buildings, Seismic isolation

This report describes a series of tests carried out to verify the performance of prototype natural rubber bearings designed for the first building in the United States built on the principles of base isolation. The cylindrical base isolation bearings consist of layers of natural rubber and thin steel plates. The tests demonstrated that the bearings were able to sustain large lateral cyclic displacements without distress. Effective vertical and lateral stiffnesses of the bearings were determined. Equivalent viscous damping ratios were calculated from the hysteretic plots. The displacement demand on the bearings was predicted on the basis of dynamic analysis.

86-2425

Modal Properties of a Base Isolated Building

G.C. Pardo, G.C. Hart
Univ. of California, Irvine, CA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1312-1316, 7 figs, 5 refs

KEY WORDS: Experimental modal analysis, Base isolation, Seismic isolation, Buildings

The modal properties of the first building in the US located in a seismic zone that is on a base isolation system are described. The design objective involves the isolation of the building from the ground with a shock isolation system which filters out the majority of the earthquake input to the structure. The modal properties are obtained by subjecting the structure to a calibrated impact (a large pendulum striking a reaction mass at the top story) while simultaneously measuring velocity data at a number of strategic locations. Estimates of damping and frequency are compared to the ambient vibration results.

86-2426

Horizontal Isolation of Sensitive Building Contents

K.L. Merz, J.C. Stoessel, J. Yagoubian, R. Haskell

ANCO Engineers, Inc., Culver City, CA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1317-1321, 5 figs

KEY WORDS: Experimental modal analysis, Base isolation, Seismic isolation, Buildings, Equipment-structure interaction

While buildings and other similar structures have design criteria for earthquake-induced loads, no similar criteria exist for the sometimes sensitive contents inside buildings. In some cases, these contents may represent the heart of the business (computers and assorted items) or valuable items such as those in a museum. Two studies were undertaken to experimentally verify horizontal isolation systems designed for a computer unit and a museum cabinet. The designs proved successful in reducing horizontal accelerations to an acceptable level.

86-2427

Base Isolating High Frequency Seismic Events

P.R. Millarke

Martin Marietta Corp., Denver, CO
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1322-1326, 4 figs, 8 refs

KEY WORDS: Experimental modal analysis, Base isolation, High frequency excitation

Some time-dependent forcing functions taken from accelerometer recordings of seismic events in California indicate that high accelerations associated with high frequency motion may be possible. Analysis by the modal acceleration method shows that for structures not designed to resist this high frequency motion, high base shears may occur. Base isolation is suggested as a method of avoiding the possibility of unacceptably high loads.

86-2428

Damped Modal Analysis of Full Base Isolation

K. Delnic

Kraftwerk Union AG, Postfach, West Germany
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1327-1334, 6 figs, 2 tables, 1 ref

KEY WORDS: Experimental modal analysis, Base isolation, Nuclear power plants, Helical springs

Damped modal analysis based on a newly developed quadratic eigenvalue solver is presented. Its special feature is the capability to analyze the free vibration mode of a multi-degree-of-freedom system as a function of the variable physical damping attached to the system at its nodes. The modal flow analysis is a helpful tool to control the structural behavior independently from the excitation. However for each excitation and desired damping value the modal integration can be performed. The method is applied to analyze the base isolation of the reactor building supported on helical springs and damper elements.

86-2429

Role of Base Isolation in the Aseismic Design of Structures

N.R. Valdya

Paul C. Rizzo Assoc., Inc., Pittsburgh, PA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1045-1051, 6 figs, 3 tables, 5 refs

KEY WORDS: Base isolation, Seismic design

Shaker table tests in the laboratory have demonstrated the feasibility of base isolation. Even more than conventional structures, sensitivity and probabilistic studies of seismic response of base-isolated structures need to be performed to augment the relatively insignificant data base. The study reported here contributes to the data base. Using relatively simple analytical models, which include material nonlinearities, probabilistic analysis of a few base-isolated structures is performed. Distributions of probabilities of exceedance of pertinent design quantities is established. Physical parameters, which are dominant in affecting seismic response, are identified. Important design considerations are discussed and, from this point of view, the role of base isolation in the aseismic design is examined.

86-2430

Design and Cost/Benefit Issues for Seismically Isolated Structures

R.L. Mayes, M.R. Button

Dynamic Isolation Systems, Inc., Berkeley, CA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1036-1044, 4 figs, 3 tables, 13 refs

KEY WORDS: Seismic isolation, Base isolation, Buildings, Bridges, Elastomers

Seismic (or base) isolation is a design concept that offers significant benefits for reducing the

earthquake damage potential in both buildings and bridges. This paper addresses the feasibility, design philosophy and cost/benefit issues of building base isolation design. Also included is a detailed design procedure for a lead-rubber bearing seismic isolation system. This is illustrated by means of an example on a twelve-story structure.

86-2431

Basic Concept and Applications of Base Isolation

I.G. Buckle, T.E. Kelly, L.R. Jones

Computech Engineering Services, Inc., Berkeley, CA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1026-1035, 8 figs, 2 tables, 13 refs

KEY WORDS: Buildings, Base isolation, Seismic isolation

Base isolation is a design strategy founded on the premise that a structure can be substantially decoupled from damaging horizontal components of earthquake motions, significantly reducing levels of force and acceleration in the structure. This paper outlines the basis of a practical base isolation system which may include energy dissipation in special purpose mechanical devices. Topics covered include basic elements of base isolation, and an overview of recent applications.

86-2432

Active Motion Compensation System for Towed Chain Arrays

G.B. Andrews

"Improve Your Odds with Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 563-543, 8 figs

KEY WORDS: Active vibration control, Towed systems

A motion-compensation system that controls the position of a cable towed behind an ocean-going vessel is discussed. An active control system that will operate in conjunction with a passive compensation system is proposed. A system model, developed from Lagrange's equations, is coded into software using ACSL, a simulation language. Data from actual at-sea tests of the passive system is fed into the model in order to establish system parameters. The effect of an active control system using a torque motor is introduced into the simulation. General results are described, with recommendations for future enhancements and improvements.

86-2433

On the Suppression of Ground Vibration by Active Force Control (4th Report; On the Hybrid Force Control)

N. Tanaka, Y. Kikushima

1-2Namiki Tsukuba Science City, Ibaraki, Japan Bull. JSME, 29 (251), pp 1548-1556 (May 1986) 19 figs, 8 refs

KEY WORDS: Machinery-induced vibrations, Ground vibration, Vibration control, Active force control

For the purpose of suppressing ground vibration as pollution produced by vibrating machines such as forge hammers, press machines, etc., this paper presents a new active hybrid force control method. By using both the characteristics of a low pass filter of an elastic support and that of a high pass filter of an active force control method, the method aims to eliminate the exciting force in the frequency range. The principle of the hybrid force control is proposed and the fundamental characteristics of the dynamic compensator are shown. From the viewpoint of the phase compensation method, the design procedure of the hybrid force control system is presented and the effectiveness of this method is clarified. To verify the control effect, an experiment is conducted.

86-2434

On the Suppression of Ground Vibration by Active Force Controller (5th Report; Experiment of the Hybrid Force Control Method)

N. Tanaka, Y. Kikushima

1-2Namiki Tsukuba Science City, Ibaraki, Japan Bull. JSME, 29 (251), pp 1557-1563 (May 1986) 16 figs, 1 table, 5 refs

KEY WORDS: Machinery-induced vibrations, Ground vibration, Vibration control, Active force control

This paper discusses the realization of the hybrid force control method from a practical point of view. First, based upon the experimental data, the design procedure of the system is presented. Second, in the suppression of the exciting force, the control effect in terms of an active damper is considered. Third, from a viewpoint of dynamic compensation, the effectiveness as well as the stabilization of the system is shown. Finally, the hybrid force control method including both the characteristics of a low-pass filter of an elastic support and that of a high-pass filter of an active force control method is realized experimentally.

86-2435

**Computer Aided Design of Vibration Isolators
Regarding Soil Interaction (VID)**

A. Nasser, S. Serag, A. El Khatib, H. Gaffer
Menoufia Univ., Shebin El-Kom, Egypt
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1132-1139, 8 figs, 5 refs

KEY WORDS: Vibration isolators, Machine foundations, Soil-foundation interaction, Computer aided design, Computer programs

The main objective of this paper is to aid designers of vibration isolators in obtaining a more exact solution to the isolation problem, taking into account soil interaction. A computer aided design technique using the machinery and soil information is introduced.

86-2436

Dynamic Vibration Absorbers for Reducing Resonance Amplitudes of Hysteretically Damped Beams

B. Candir, H.N. Ozguven
Middle East Tech. Univ., Ankara, Turkey
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1628-1635, 5 figs, 2 tables, 12 refs

KEY WORDS: Dynamic vibration absorption (equipment), Beams, Hysteretic damping

The parameters of a viscously damped dynamic vibration absorber can be optimized to minimize a specific resonance of a structure. In this study, the optimum absorber parameters are found by solving a min-max problem (minimization of the maximum response in the frequency range of interest). The response of a structurally damped beam and absorber system is determined by the assumed-modes method. Harmonic excitations with constant and frequency-squared amplitudes are considered. The optimum parameters of the absorber suppressing the first or second resonance amplitudes of a cantilever beam are numerically determined and the results are presented in the form of nondimensional graphs. The graphs are prepared for a given structural damping factor after studying the effect of structural damping on the optimum absorber parameters. The optimum absorber parameters found by this method are compared with those obtained by the approximate method employing an equivalent single-degree-of-freedom system.

86-2437

An Active Vertical Suspension for Track/Vehicle Systems

T. Yoshimura, N. Ananthanarayana, D. Deepak

Tokushima Univ., Tokushima, Japan

J. Sound Vib., 106 (2), pp 217-225 (Apr 22, 1986) 6 figs, 14 refs

KEY WORDS: Suspension systems (vehicles), Tracked vehicles, Active vibration control

Optimal control theory is used to formulate and solve the problem of design of an active suspension system to control vertical vibration of a track/vehicle system. The active suspension system is taken as a cascade arrangement of a Kalman filter and the optimal controller. A noisy measured data sequence of the track unevenness is used as the input. As a numerical example, an active suspension of a simple carbody of the Indian Railways is presented.

SPRINGS

86-2438

Segmented Tubular Cushion Springs and Spring Assembly

L.A. Haslim
NASA Ames Res. Ctr., Moffett Field, CA
U.S. Pat. Appl. 6-746 160/GAR, 39 pp (June 1985)

KEY WORDS: Springs, Energy absorption

A spring which includes a tube with an elliptical cross section, with the greater axial dimension extending laterally and the lesser axial dimension extending vertically is disclosed. A plurality of cuts in the form of slots passing through most of a wall of the tube extend perpendicularly to a longitudinal axis extending along the tube. An uncut portion of the tube wall extends along the tube for bonding or fastening the tube to a suitable base, such as a bottom of a seat cushion.

TIRES AND WHEELS

86-2439

Identification of the Damping Matrix for Tires

D.J. Inman, S.K. Jha
State Univ. of New York, Buffalo, NY
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1078-1080, 6 refs

KEY WORDS: Tires, Elastomers, Linking analysis and test, Viscous damping, Modal analysis

In modeling structures, the dissipation in the system is usually the most difficult element to

represent. This is especially true in complex structures such as the cord rubber composite materials used in tires. The work presented here applies a method of modeling the dissipation in a structure from experimental data combined with accepted nondissipative finite element models. The result of the described procedure is a linear nonconservative multiple degree-of-freedom model of a test structure that correctly predicts the transient response of the structure to arbitrary inputs.

BLADES

86-2440

Modal Analysis of a Moving Band Under Cutting Loads

W.Z. Wu, C.D. Mote, Jr.

Univ. of Missouri, Rolla, MO

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1621-1627, 10 figs, 11 refs

KEY WORDS: Modal analysis, Band saws, Woodworking machines, Blades,

Excessive band vibration directly contributes to the poor cutting accuracy and surface quality, raw material waste, gullet cracking, and increased downtime of bank mills. Bending-torsional coupled transverse vibrations of a cutting blade are investigated by using a linear undamped axially moving thin beam model. An accurate, comprehensive, fast and inexpensive numerical method for efficient analyses of the natural frequencies and mode shapes of a cutting blade has been developed. Cutting speed, cutting loads and possible constraints are incorporated in the analysis.

86-2441

Finite Element Modal Analysis of Steam Turbine Blades

J.M. Steele

Stress Technology Inc., Rochester, NY

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1374-1381, 16 figs, 3 tables, 7 refs

KEY WORDS: Modal analysis, Turbine blades, Finite element technique

Finite element analysis is particularly well suited to dynamic analysis of steam turbine blades. The blades have a complex geometry, are affected by high centrifugal stresses which raise natural frequencies and are subjected to signifi-

cant harmonic forcing which can produce significant dynamic stresses. Modal finite element analyses of two, typical steam turbine blades are presented. Parametric studies, for one of the blades were performed to determine the convergence of natural frequencies as functions of element density and number of retained master degrees of freedom.

86-2442

Modelling of Turbine Blades for Stress and Dynamic Analysis

M.S. Gadala, T.P. Byrne

Ontario Hydro Research, Toronto, Ontario, Canada

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1220-1227, 13 figs, 4 tables, 11 refs

KEY WORDS: Turbine blades, Mathematical models

Modeling of turbine blades is of major importance for the analysis and design of turbines for power plants. Various design features for locking grooves, blade root serrations, and lacing wires must be assessed via stress and dynamic analysis. This paper presents a comparative study and assessment for various 2-D and 3-D blade models addressing one or more of the above considerations. Basic steps of a complete blade dynamic analysis are then provided. Through an actual working example, it is shown that the analysis of full-scale blade models can be achieved through the analysis of reduced models.

BEARINGS

86-2443

Calculation of the Dynamic Coefficients of a Journal Bearing, Using a Variational Approach

P. Klit, J.W. Lund

Engineering Academy of Denmark, Lyngby, Denmark

J. Trib., Trans. ASME, 108 (3), pp 421-425 (July 1986) 3 figs, 4 refs

KEY WORDS: Journal bearings, Dynamic coefficients

The dynamic bearing coefficients are obtained from a solution to the variational equivalent of Reynolds equation. A perturbation method is applied to find the individual dynamic coefficients. The finite element method is used in the numerical evaluation of the equations. The flow

is assumed to be laminar, the lubricant is Newtonian. Allowance is made for viscosity-temperature dependency in circumferential and axial directions.

86-2444

Ball Bearing Response to Cage Unbalance

P.K. Gupta, J.F. Dill, J.W. Artuso, N.H. Forster
PKG Inc., Clifton Park, NY
J. Trib., Trans. ASME, 108 (3), pp 462-467 (July 1986) 11 figs, 2 tables, 9 refs

KEY WORDS: Ball bearings, Unbalance mass response, Computer programs, Experimental data

Motion of the cage in a high-speed angular contact ball bearing is experimentally investigated as a function of prescribed unbalance, up to operating speeds corresponding to three million DN. The predictions of cage motion made by the recently developed computer model, ADORE, are validated in the light of the experimental data. It is shown the cage whirl velocity is essentially equal to its angular velocity at all levels of unbalance and over a wide range of operating conditions. ADORE predictions, over the entire range of unbalance and bearing operating conditions, are in very good agreement with the experimental observations.

86-2445

Quasi-Modal Vibration Control by Means of Active Control Bearings

K. Nonami, D.P. Fleming
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. NASA-TM-87232, 12 pp (1986) N86-21856/7/GAR

KEY WORDS: Modal analysis, Bearings, Active vibration control, Modal control

A design method of an active control bearing system with only velocity feedback is investigated. The study provides a new quasi-modal control method for a control system design of an active control bearing system in which feedback coefficients are determined on the basis of a modal analysis. Although the number of sensors and actuators is small, this quasi-modal control method produces a control effect close to an ideal modal control.

GEARS

86-2446

Lubricant and Additive Effects on Spur Gear Fatigue Life

D.P. Townsend, E.V. Zaretsky, H.W. Scibbe

NASA Lewis Res. Ctr., Cleveland, OH
J. Trib., Trans. ASME, 108 (3), pp 468-475 (July 1986) 4 figs, 8 tables, 19 refs

KEY WORDS: Spur gears, Fatigue life, Fatigue tests, Lubrication

Spur gear endurance tests were conducted with six lubricants using a single lot of consumable-electrode vacuum melted (CVM) AISI 9310 sput gears. The sixth lubricant was divided into four batches each of which had a different additive content. Lubricants tested with a phosphorous-type load carrying additive showed a statistically significant improvement in life over lubricants without this type additive.

86-2447

Approximate Solution of a Gear System Subjected to Random Excitation

K. Sato, S. Yamamoto, O. Kamada, N. Takatsu
Utsunomiya Univ., Utsunomiya, Japan
Bull. JSME, 29 (251), pp 1586-1589 (May 1986) 5 figs, 14 refs

KEY WORDS: Gears, Random excitation, Approximation methods

Forced vibration of a gear system excited by transmission error having a period equal to the meshing period and by a random external force, is analyzed approximately by means of an averaging method. Some numerical examples are given. To facilitate analytical treatment, the time varying parameter system is transformed into a time invariant parameter system.

86-2448

Vibration of Power Transmission Helical Gears (Approximate Equation of Tooth Stiffness)

K. Umezawa, T. Suzuki, T. Sato
Tokyo Institute of Technology, Yokohama, Japan
Bull. JSME, 29 (251), pp 1605-1611 (May 1986) 15 figs, 2 tables, 18 refs

KEY WORDS: Helical gears, Torsional vibration, Finite difference technique

An approximate equation has been proposed to clarify the rotational vibration behavior of power transmission helical gear pairs with comparatively narrow facewidth. It has been based on the theoretical deflection solved by one of the authors using the finite difference method. And the rotational vibration has been treated as a single-degree-of-freedom system and the meshing resonance frequency of it has been obtained. Its propriety is verified by measuring the accelera-

tion for each gear pair belonging to the three categories classified by contact ratio. It is found that the meshing resonance frequencies calculated by use of the proposed equation agrees with experimental values.

FASTENERS

86-2449

LCC Solder Joint Fatigue Analysis Procedure
W.E. Desaulnier, Jr., T.E. LaFlamme, W.B. Ammerman, M.C. Binder
Hamilton Standard Div, United Tech. Corp.,
Windsor Locks, Canada
"Environmental Tech--Coming of Age", Proc.
32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 6-19, 15
figs, 2 tables, 12 refs

KEY WORDS: Joints, Electronic instrumentation,
Fatigue life

A simplified procedure has been developed which now makes it practical to perform a reasonably accurate inelastic fatigue analysis of critical LCC solder joints in any electronic unit. The procedure requires only elastic stress analysis results and it is completely general regarding the loads and designs it can handle. Both post-mounted and card guide mounted PCB electronic unit designs can be analyzed. Vibration curvature and thermal shear and curvature loadings are all handled by the procedure. It includes a general fatigue curve equation which can account for temperature, rate, grain size, gold content and stress state triaxiality effect. The entire procedure has been programmed and effectively applied to evaluate various designs.

86-2450

Loosening of Threaded Fastenings by Vibrations
S. Harnchoowong
Ph.D. Thesis, Univ. of Wisconsin, Madison, WI,
200 pp (1985) DA8601103

KEY WORDS: Fasteners, Bolts, Loosening, Vibration excitation

Loosening of threaded fastenings by vibrations was divided into two processes: an increasing bolt load process and a decreasing bolt load process. There were two parts of calculation manipulated in each process. The first part was to calculate the load distribution in the engaged threads by modifying Sopwith's model. This thread load was used to compute stress, strain, and displacement in a bolt and a nut. The

second part was to calculate the angle of nut loosening by using the results obtained from two torque equilibrium equations, one for a bolt and the other for a nut.

SEALS

86-2451

Pressure and Squeeze Effects on the Dynamic Characteristics of Elastomer O-Rings Under Small Reciprocating Motion
I. Green, I. Etsion
Technion Univ., Haifa, Israel
J. Trib., Trans. ASME, 108 (3), pp 439-445 (July 1986) 5 figs, 3 tables, 8 refs

KEY WORDS: Rings, Seals, Elastomers

A test procedure is described by which quick measurements of stiffness and damping coefficients of elastomer O-rings can be made for a wide range of the parameters affecting O-ring dynamics. Tests were performed to investigate the effects of squeeze and pressure on the dynamic characteristics of Nitrile (Buna N) and Fluorocarbon (Viton 75) O-rings. Results of these tests are presented and discussed.

86-2452

Theory Versus Experiment for the Rotordynamic Coefficients of Annular Gas Seals: Part 1 -- Test Facility and Apparatus
D.W. Childs, C.E. Nelson, C. Nicks, J. Scharrer
Texas A&M Univ., College Station, TX
J. Trib., Trans. ASME, 108 (3), pp 426-432 (July 1986) 11 figs, 10 refs

KEY WORDS: Seals, Dynamic coefficients, Experimental data, Testing techniques, Testing instrumentation

A facility and apparatus are described for determining the rotordynamic coefficients and leakage characteristics of annular gas seals. The apparatus has a current top speed of 8000 cpm with a nominal seal diameter of 15.24 cm (6 in). The air supply unit yields a seal pressure ratio of approximately 7. The inlet tangential velocity can also be controlled. An external shaker is used to excite the test rotor. The apparatus has the capability to independently calculate all rotordynamic coefficients at a given operating condition with one excitation frequency.

86-2453

Theory Versus Experiment for the Rotordynamic Coefficients of Annular Gas Seals: Part 2 — Constant-Clearance and Convergent-Tapered Geometry

C.C. Nelson, D.W. Childs, C. Nicks, D. Elrod
Texas A&M Univ., College Station, TX
J. Trib., Trans. ASME, 108 (3), pp 433-438 (July 1986) 9 figs, 8 refs

KEY WORDS: Seals, Dynamic coefficients, Stiffness coefficients, Experimental data

An experimental test facility is used to measure the leakage and rotordynamic coefficients of constant-clearance and convergent-tapered annular gas seals. The results are presented along with the theoretically predicted values. Of particular interest is the prediction that optimally tapered seals will have significantly larger direct stiffness than straight seals. The experimental results verify this prediction. Generally the theory does quite well, but fails to predict the large increase in direct stiffness when the fluid is prerotated.

STRUCTURAL COMPONENTS

CABLES

86-2454

Modal Coupling in the Free Nonplanar Finite Motion of an Elastic Cable

F. Benedettini, G. Rega, F. Vestroni
Meccanica, 21 (1), pp 38-46 (Mar 1986) 12 figs, 1 table, 18 refs

KEY WORDS: Cables, Elastic properties, Modal coupling

In the finite motions of a suspended elastic cable the in-plane and out-of-plane oscillations are coupled, which is in contrast with what is predicted by the theory of small oscillations. To study the phenomenon of nonlinear coupling, a simple but meaningful two degree-of-freedom model is referred here, one parameter being used to describe the in-plane motion and the other the out-of-plane motion. The solution of the dynamic equilibrium equations is accomplished by an order-three perturbational expansion, which furnishes the time solution of the two displacement parameters. The modification of the free oscillations due to the exchange of energy between the two modes in absence of

internal resonance is studied for different initial conditions and the effect of modal coupling is evidenced.

86-2455

Spectral Analysis of Cable Stay Vibration

F. Eken
Ph.D. Thesis, Tulane Univ., 157 pp (1985)
DA8606163

KEY WORDS: Cables, Cable stayed structures, Suspension bridge, Spectrum analysis

Cable stay vibration data was obtained from the cable-stayed suspension bridge at Luling, Louisiana. Cable stay motion is harmonic in nature and is modeled as a linear system consisting of a set of second-order resonances. While traditional processing of this data using harmonic analysis provides information about the harmonic frequencies and the average excitation at these frequencies, in this investigation additional features of this data such as the instantaneous modal excitations and estimates of modal damping coefficients were obtained using the methods of complex demodulation and the ZOOM FFT. Modal resonance characteristics of the cable stay vibration were examined using the ZOOM-EFT technique. The input to the system is assumed to be band limited white noise having a constant power spectrum over a very narrow band of frequencies. The output of the system is either the output from a single accelerometer or the semi-major axis of the elliptical trajectory computed from the output of two accelerometers. Estimates of modal damping coefficients were obtained for both representations of the output.

BEAMS

86-2456

A Study on Non-Proportionally Damped Beams

H.N. Ozguven
Middle East Technical Univ., Ankara, Turkey
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1081-1087, 4 figs, 1 table, 13 refs

KEY WORDS: Beams, Damped structures, Linking analysis and test, Modal analysis

Vibrational characteristics of nonproportionally damped structures can quite accurately be predicted by complex mode superposition. However, solving a complex eigenvalue problem and using complex modes increase the computational effort considerably. Approximate methods,

therefore, are preferred in several applications. Almost in all approximate modal analysis methods, real modal vectors are employed by making proportional damping approximation. In this work dynamic behavior of damped beams, harmonically excited at frequencies around a resonance frequency is investigated by using results of a set of experiments conducted with proportionally and nonproportionally damped aluminum beams. The main attention is focused on the contribution of the in-phase component of the receptance (or inertance) to the total response at undamped natural frequencies as well as at resonance frequencies. The change of this contribution by the point of excitation and/or point of measurement is also investigated.

86-2457
A Finite Element for Dynamic Analysis of Beams and Space Frames

M. Olsson

Lund Univ., Lund, Sweden

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 884-890, 3 figs, 2 tables, 11 refs

KEY WORDS: Modal analysis, Beams, Finite element technique, Coupled response

A finite element for analysis of beams and beam structures has been developed. Its use in dynamic analysis is emphasized in this paper. The beam element is capable of handling coupled vibrations and, as options, second-order effects, bending shear deformations, rotatory inertia and warping torsion (Vlasov torsion). The choice of reference axes is not restricted to the centroidal and shear center axes but can be chosen arbitrarily. Two numerical examples demonstrate some of the possibilities of the element presented.

86-2458
Determination of Boundary Conditions on African Xylophone Beams Using Modal Analysis

J. Njock Libii

Indiana Univ.-Purdue Univ., Ft. Wayne, ID

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1071-1077, 5 figs, 6 tables, 4 refs

KEY WORDS: Beams, Musical instruments, Modal analysis, Linking analysis and test, Geometric effects

Xylophone beams are modeled as Euler beams in free lateral vibration with free ends. The response of such beams to a sudden impact at

their midpoint is investigated analytically and experimentally to determine the boundary conditions that are applicable. The material properties as well as the boundary conditions were assumed constant for all beams and the relationship between fundamental frequency and geometry was studied. Theoretical frequencies were found to be consistently lower than measured ones by thirteen percent.

PLATES

86-2459

Free Vibrations of a Plate with an Inner Support

P.A.A. Laura, V.H. Cortinez

Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina

J. Sound Vib., 106 (3), pp 409-413 (May 8, 1986)
2 figs, 8 refs

KEY WORDS: Plates, Fundamental frequencies, Flexural vibrations

The title problem is tackled by using a simple polynomial coordinate function and the Rayleigh-Schmidt method. It is assumed that the inner support is parallel to the free edge. When the support coincides with the free edge the frequency equation degenerates properly into the case of a simply supported edge. Numerical results are presented for the situation where two opposite edges are simply supported and the edge parallel to the free edge is either clamped or simply supported.

86-2460

A Study of Noise Source Identification on Plate Excited by Structure-Borne Sound Using the Acoustic Intensity Method

Jae Eung Oh, Jun Chul Park, Sung Ha Yum

Han Yang Univ., Seoul, Korea

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 952-956, 9 figs, 1 table, 6 refs

KEY WORDS: Plates, Noise source identification, Acoustic intensity method

In studies on noise reduction, it is necessary to know the generation mechanism of sound to identify the noise sources. As there is a complex relation between the structural surface vibration and the radiated sound power resulting from these vibrations, a simplified radiation model is used which originally was developed as a verification tool for the acoustic intensity measurement procedure. Cross correlation

between the displacement pattern of the resonant vibrational mode and experimentally determined intensity pattern was found.

86-2461

Impulse Response of an Infinitely Long Thick Strip Plate

S. Chonan, N. Nozawa

Tohoku Univ., Sendai, Japan

J. Sound Vib., 106 (3), pp 481-489 (May 8, 1986)
6 figs, 10 refs

KEY WORDS: Plates, Elastic foundations, Impulse response, Rotatory inertia effects, Transverse shear deformation effects

A study of the dynamic response of an infinitely long thick strip plate subjected to an impulsive load is presented. The plate is simply supported along the edges and resting on an elastic foundation. The problem is studied on the basis of a plate theory in which the effects of rotatory inertias and shear deformations are retained. Governing equations are solved by applying the methods of the Laplace transform with respect to time and the Fourier transform with respect to a longitudinal space variable. Dynamic coefficients (maximum dynamic displacement/static displacement, maximum dynamic bending moment/static bending moment) are calculated numerically for plates subjected to a step line load and shown graphically for various values of the parameters included.

86-2462

Natural Frequency of an Edge-Fixed Disc in Contact with a Liquid

H. Takada, K. Ohno

Yokohama National Univ., Yokohama, Japan

Bull. JSME, 29 (251), pp 1544-1547 (May 1986)
6 figs, 4 refs

KEY WORDS: Plates, Disks, Fluid-induced excitation, Natural frequencies,

This paper deals with the natural frequency of an edge-fixed disk in contact with a liquid, which acts as an added mass to the disk reducing its natural frequency. Calculations and experiments are carried out for two cases. The experimental results agree well with the calculations by means of the finite element method within 4.3% error for the nodeless mode and for the mode with one diametral- and zero circular node. A reduction formula for the reducing ratio of the frequency is derived for arbitrary disk thickness, radius and density and also for arbitrary liquid density.

86-2463

Response of Plates to Pulse Excitation

G. Chandrasekharappa, H.R. Srirangarajan

Indian Institute of Technology, Bombay, India

Mech. Res. Comm., 13 (2), pp 107-117 (Mar/Apr 1986) 2 figs, 1 table, 7 refs

KEY WORDS: Plates, Large amplitude vibrations, Pulse excitation, Nuclear weapons effects, Aircraft

In this paper, the ultraspherical polynomial approximation technique is presented for the large-amplitude vibrations of thin plates subjected to step function loading, neglecting the longitudinal and rotatory inertia forces.

86-2464

Coupling of Lagrange Interpolation Modal Analysis and Sensitivity Analysis in the Determination of Anisotropic Plate Rigidities

W.P. DeWilde, H. Sol, M. Van Overmeire

Univ. of Brussels, Brussels, Belgium

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1058-1063, 4 figs, 3 tables, 3 refs

KEY WORDS: Plates, Linking analysis and test, Experimental modal analysis, Numerical methods

The paper presents further developments of a problem previously exposed by the authors in 2nd IMAC, namely the coupling of experimental modal analysis and numerical analysis in order to obtain the plate rigidities. The knowledge of these plate rigidities enables the calculation of elastic material constants which can be used e.g. as input data for finite element models. The tuning operation is based on the calculation of sensitivities of the eigenvalues for parameter changes. The initial guess for the plate rigidities is calculated using the measured mode shapes of the test plates. The whole procedure is programmed in a FORTRAN program NATIDEN.

86-2465

Natural Frequencies and Mode Shapes of a Free Rectangular Plate as a Function of the Aspect Ratio

D.L. Gregory, D.O. Smallwood

Sandia National Laboratories, Albuquerque, NM

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1000-1005, 5 figs, 1 table, 6 refs

KEY WORDS: Rectangular plates, Natural frequencies, Mode shapes, Geometric effects, Experimental modal analysis

Numerous modal systems are now available and new users are continually being introduced to these systems. A simple test structure would be useful to compare these systems on a common basis and would also provide a means to help train new users. Efforts to develop such a structure led to the analysis of free rectangular plates. The natural frequencies as a function of the aspect ratio (ratio of width to length) were analyzed to find an aspect ratio which would yield a desirable distribution of modal frequencies. A desirable distribution includes both widely separated and closely coupled modes. Results for sensitivity studies of mode shapes and frequencies to plate parameters are also given.

86-2466

Experimental Investigation of Asymptotic Modal Analysis for a Rectangular Plate

Y. Kubota, E.H. Dowell

Duke Univ., Durham, NC

J. Sound Vib., 106 (2), pp 203-216 (Apr 22, 1986), 10 figs, 10 refs

KEY WORDS: Rectangular plate, experimental modal analysis, Point source excitation

Experimental investigations of the response of a rectangular plate under a point random force have been performed to verify the asymptotic behavior predicted by asymptotic modal analysis (AMA). Measurements have been made for various frequency bandwidths, center frequencies, and locations of the point force. The experimental results approach the results predicted by AMA as the frequency bandwidth becomes large. Moreover, experimental results show that the responses at all points of the plate except for some special areas become the same as the frequency bandwidth becomes large. However, the ratio of experimental results to AMA results has a greater variation from unity when the location of the point force is near the edge of the plate, than when the location of the point force is at the center of the plate. All experimental results show good agreement with the expected results from AMA.

86-2467

A Note on Transverse Vibrations of a Rectangular Plate with a Free, Rectangular, Corner Cut-Out

P.A.A. Laura, P.A. Laura, V.H. Cortinez

Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina

J. Sound Vib., 106 (2), pp 187-192 (Apr 22, 1986) 4 figs, 10 refs

KEY WORDS: Rectangular plates, Flexural vibrations, Hole-containing media, Rayleigh-Ritz method

An approximate solution to the title problem is presented, obtained by using the Rayleigh-Ritz method. The analysis is presented for the case of simply supported and clamped plates. For the case of a rigidly clamped plate results are presented of numerical experiments on minimizing the calculated value of the fundamental frequency coefficient by using Schmidt's approach. An experimental investigation is described on a clamped square plate with a free square, corner cut-out, which has led to the conclusion that the fundamental frequency coefficient remains practically invariant with respect to size when compared with the frequency coefficient of the fully clamped plate. A similar conclusion is arrived at by means of the mathematical model. The problem under consideration is important from a practical viewpoint since cut-outs of the type considered here are quite common in engineering practice.

86-2468

Static and Dynamic Deflections of Plates of Arbitrary Geometry by a New Finite Difference Approach

M.C. Bhattacharya

Univ. of Liverpool, Liverpool, England

J. Sound Vib., 107 (3), pp 507-521 (June 22, 1986) 4 figs, 3 tables, 12 refs

KEY WORDS: Rectangular plates, Finite difference technique

Finite difference solutions for the static and dynamic displacements of a plate undergoing vibration are presented. The approach presented differs from the conventional methods in which the derivatives are expressed by their difference equivalents. Here the difference equations are obtained as solutions to the fourth order biharmonic equation. A single space varying drive number is found which varies from node to node and characterizes the true mode shape of the plate at a node. The technique presented can be applied to finite elements of triangular, rectangular or quadrilateral geometry without any restriction.

86-2469

Numerical Analyses of Flexural Vibrations of Tapered Thickness Rectangular Plates

P.A.A. Laura, C. Shangchow, R. Gelos, R.D. Santos

Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina

J. Sound Vib., 106 (3), pp 415-418 (May 8, 1986)
1 fig, 1 table, 5 refs

KEY WORDS: Rectangular plates, Flexural vibrations, Variable cross section, Fundamental frequencies, Numerical methods

The fundamental frequencies of vibration of a clamped rectangular plate with thickness varying in a bilinear fashion in the x-direction are determined, for various values of the plate parameters, by two different approaches: the Rayleigh-Schmidt minimization procedure; and a finite element algorithm.

86-2470

Free Vibration Analysis of Right Triangular Plates with Combinations of Clamped-Simply Supported Boundary Conditions

D.J. Gorman
University of Ottawa, Ottawa, Ontario, Canada
J. Sound Vib., 106 (3), pp 419-431 (May 8, 1986)
10 figs, 7 tables, 5 refs

KEY WORDS: Plates, Triangular bodies, Boundary condition effects, Method of superposition

An accurate analytical solution is obtained for the free vibration of right triangular plates with all possible combinations of clamped and simply supported edge conditions. The method of superposition as described by the author in an earlier publication is utilized. A slight modification is made to the earlier building blocks in order to facilitate computations. Eigenvalues and mode shape information are provided for the first four modes of free vibration with a large range of plate aspect ratio. This appears to constitute the first accurate and comprehensive treatment of this family of problems.

86-2471

Dynamic Response of Circular Plates in Contact with a Fluid Subjected to General Dynamic Pressures on a Fluid Surface

K. Nagaya, K. Nagai
Gunma Univ., Gunma, Japan
J. Sound Vib., 106 (2), pp 333-345 (Apr 22, 1986) 12 figs, 15 refs

KEY WORDS: Circular plates, Fluid-induced excitation

A method for solving dynamic response problems of a circular plate in contact with a fluid whose surface is excited by general dynamic pressures is presented. By utilizing the Fourier expansion and the Laplace transform methods, the expres-

sion for the dynamic response of displacement is obtained in a general form which is applicable to general dynamic pressures. As applications, numerical calculations have been carried out for three types of sinusoidal, trapezoidal and explosive pressures. The results obtained in a certain type of impact pressure are compared with the exact ones.

86-2472

Vibration of a Circular Disk as a Test Method for Damping Characteristics of Constrained Layer Material

V.O. Shestopal, P.C. Goss
National Materials Handling Bureau, New South Wales, Australia
J. Sound Vib., 106 (3), pp 377-390 (May 8, 1986)
5 figs, 5 tables, 9 refs

KEY WORDS: Disks, Circular plates, Sandwich structures, Damping coefficients

The theoretical analysis of free vibrations of a disk of constrained layer sandwich material is considered. The results enable the real and imaginary parts of the shear parameter to be determined from experimental data. A correction for a small mass attached to the center of a disk is introduced. An example of test results illustrates the method. An exact method involving numerical solution of the governing differential equation has been checked by approximate formulae based on potential energy of deformation.

86-2473

A Note on Vibrating Polar Orthotropic Circular Plates Carrying Concentrated Masses

R.O. Grossi, P.A.A. Laura, Y. Narita
Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina
J. Sound Vib., 106 (2), pp 181-186 (Apr 22, 1986) 1 fig, 4 tables, 10 refs

KEY WORDS: Circular plates, Mass-plate systems

The fundamental frequency of vibration of a circular plate of polar orthotropy carrying concentrated masses is determined by using an extension of the Rayleigh-Schmidt technique and a Ritz-Lagrange multipliers method. Numerical results are presented for clamped and simply supported plates for several combinations of orthotropic parameters and values of the concentrated mass to plate mass ratio.

86-2474

Transient Far Field Waveform on the Axis of an Elastic Circular Plate Excited by a Pulsed Axial Point Source

I. Nakayama, A. Nakamura

Osaka Univ., Osaka, Japan

J. Sound Vib., 106 (2), pp 267-274 (Apr 22, 1985) 3 figs, 1 table, 5 refs

KEY WORDS: Circular plates, Point source excitation, Pulse excitation

The transient waveform radiated from a thin elastic clamped circular plate set in a baffle is investigated when the plate is excited axisymmetrically by a spherical single triangular sound pulse. An expression for the on-axis transient waveform in the far field is obtained in the time domain. Some numerical calculations are made for a circular plate of duralumin, and then the deformation of the waveform due to the spherical excitation is discussed and compared with that in the case of plane wave excitation.

SHELLS

86-2475

An Analytical Method for the Vibrational Frequencies of Shells Having Uniformly Distributed Holes

L. Papa, R. Cattaneo

Rome Univ., Italy

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1367-1369, 2 figs, 6 refs

KEY WORDS: Cylindrical shells, Hole-containing media, Experimental modal analysis, Linking analysis and test

The vibrational frequencies are investigated for circular cylindrical thin-walled shells having uniformly spaced holes and height characteristic wave-length. A sinusoidal law to take into account holes distribution and hence the variation of inertial moment and mass, is proposed. A formula for the determination with good approximation of the first bending vibrational frequency is obtained by the application of the Bubnov-Galerkin method.

86-2476

Geometric and Material Nonlinear Dynamic Analysis of Complex Shells

S. Saigal

Ph.D. Thesis, Purdue Univ., 169 pp (1985)
DA8606610

KEY WORDS: Shells, Nonlinear theories, Tires

A 48 degree-of-freedom doubly curved quadrilateral thin shell element, including the effect of both material and geometric nonlinearities, is formulated and appropriate numerical procedures are adopted for the development of a systematic and efficient approach for static and dynamic nonlinear analysis of general shell structures. A systematic choice of examples is solved and compared with available solutions to evaluate the formulations and procedures recommended. As an application of the present element, a detailed study of the static contact of an inflated radial automotive tire with rigid surface is conducted.

86-2477

Vibration of Rotating Prestressed Cylindrical Shells

T. Saito, Y. Tsukahara, M. Endo

Tokyo Institute of Tech., Tokyo, Japan

Bull. JSME, 29 (251), pp 1572-1578 (May 1986) 7 figs, 13 refs

KEY WORDS: Cylindrical shells, Rotating structures, Natural frequencies

The frequency analysis is presented for rotating cylindrical shells subjected to the initial stresses which are generated by torque, external pressure or axial compression load. Consequently, it is found that, though the natural frequencies decrease depending upon the state of the initial stresses, even in the case of rotating prestressed cylindrical shells the instability phenomenon cannot be observed. The dependence of the frequencies upon the rotating speeds is approximately represented by the simple relation for a thin rotating ring provided the frequencies and rotating speeds are normalized by the natural frequencies of a nonrotating cylindrical shell.

86-2478

Analytical and Experimental Comparisons of Modal Properties of a Flood Water Storage Tank

G.L. Thinnies, W.T. Dooley, V.W. Gorman

EG&G Idaho, Inc., Idaho Falls, ID

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1064-1070, 8 figs, 2 tables, 5 refs

KEY WORDS: Storage tanks, Water, Linking analysis and test, Experimental modal analysis

Comparisons of measured frequencies, mode shapes, and damping from experimental modal testing and analytical predictions have been performed on a vertically standing 90,000 liter flood water storage tank. The purpose of the study was to compare the accuracy of analytical

calculations with experimentally obtained data. The need for this comparison arises because safety assessments of the integrity of such vessels are normally based upon analyses which have not usually been validated by experiments. Results of the analyses are presented, comparisons to test data are shown, and conclusions and recommendations are made as a result of these studies.

PIPES AND TUBES

86-2479

Dynamics of Finite-Length Tubular Beams Conveying Fluid

M.P. Paidoussis, T.P. Luu, B.E. Laithier
McGill Univ., Montreal, Quebec, Canada
J. Sound Vib., 106 (2), pp 311-331 (Apr 22, 1986) 8 figs, 3 tables, 24 refs

KEY WORDS: Pipes, Tubes, Beams, Timoshenko theory, Fluid-filled containers

The dynamics of stability of short tubes conveying fluid is re-examined by means of Timoshenko beam theory for the tube and a three-dimensional fluid-mechanical model for the fluid flow, rather than the plug-flow model utilized heretofore. The tubes considered are either clamped at both ends or cantilevered; in the latter case, special "outflow models" were introduced to describe the boundary conditions on the fluid exiting from the free end. By comparison with experiments, it is shown that this refined theory is necessary for describing adequately the dynamical behavior of extremely short tubes, although Timoshenko beam theory, together with a plug-flow model, are quite satisfactory for relatively longer short tubes; for long tubes, Euler-Bernoulli beam theory and a plug-flow model are perfectly adequate.

86-2480

A Flow Visualization Study of Flow Development in a Staggered Tube Array

A. Abd-Rabbo, D.S. Weaver
McMaster Univ., Hamilton, Ontario, Canada
J. Sound Vib., 106 (2), pp 241-256 (Apr 22, 1986) 10 figs, 23 refs

KEY WORDS: Tube arrays, Fluid-induced excitation

A flow visualization technique has been used to examine the flow development and behavior in a rotated square array of flexible tubes with a pitch-to-diameter ratio of 1.41 in a water cross-

flow. Also examined is the case of a single flexible tube in an otherwise rigid tube array. Results pertinent to the basic tube excitation mechanisms, vorticity shedding, turbulence and fluidelastic instability are presented including tube response curves, frequency response spectra and flow visualization photographs.

86-2481

Automotive Exhaust Pipe: The Modal Analysis Approach for Design and Testing

B. Piombo, R. Dardano, G. Belingardi, M. Pavese
Politecnico de Torino, Torino, Italy
Int'l. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1020-1025, 4 figs, 2 tables, 1 ref

KEY WORDS: Exhaust systems, Pipes, Fatigue life, Experimental modal analysis

The application of the modal analysis to the vibrational study of an automotive exhaust pipe is illustrated. The knowledge of the vibrational response of the pipe is fundamental for the fatigue life prediction and for duration tests. The test procedure is discussed, pointing out the necessity of the use of a three axis accelerometer and a four channel signal analyzer to get a convenient picture of the motion of the pipe. The advantages obtained using the modal analysis technique are enhanced, both for design and testing.

86-2482

Pulsatory Flow in Curved Pipes of Rectangular Cross-Section

M. Sumida, K. Sudou
Yonago National College of Technology, Yonago, Japan
Bull. JSME, 29 (251), pp 1471-1478 (May 1986) 14 figs, 10 refs

KEY WORDS: Curved pipes, Rectangular bodies, Fluid-induced excitation, Pulse excitation

Numerical analysis was made of a fully developed laminar flow in curved pipes of square cross-section under conditions where an oscillatory component of flow was superimposed on a steady mean flow. Velocity profiles, stream lines of secondary flow and distribution of wall shearing stresses were calculated in a wide range of various parameters. The kinetic energy of the secondary flow and the resistance factor were described.

DUCTS

86-2483

Numerical Modelling for Acoustic Fields in Multimode Waveguide

V. Martin

Laboratoire de Mechanique et d'Acoustique,
Marseille, France

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1208-1214, 5 figs, 4 refs

KEY WORDS: Ducts, Waveguide analysis, Acoustic waves, Wave propagation, Modal analysis

In order to control sources which have to reproduce a given vibratory field, the propagation in a multimode waveguide is simulated. Helmholtz's equation describes the harmonic field. The inverse problem is to find to what voltage the sources must be submitted in order to radiate modes of a given amplitude, this on a cross-section of the duct. The iterative method of conjugate gradient allows one to obtain the solution. A method which is almost direct; i.e., that of multiplicative coefficients, gives more accurate results more rapidly. To conclude on these numerical aspects, a simulation of active suppression of an acoustic multimode wave is developed.

86-2484

Numerical Analysis of the Wave Propagation in a Duct with an Area Change by Random Choice Method

H. Kashimura, N. Iwata, M. Nishida

Kitakyushu College of Technology, Kitakyushu, Japan

Bull. JSME, 29 (251) pp 1440-1445 (May 1986) 13 figs, 1 table, 16 refs

KEY WORDS: Ducts, Variable cross section, Shock wave propagation, Numerical methods

The random choice method (RCM) was used to numerically solve shock propagation in a Laval nozzle and a Ludwieg tube. In quasi-random sampling procedure the van der Corput method was used. The RCM analysis predicts five unique possible wave patterns. The starting process of the Ludwieg tube was also numerically analyzed using the RCM.

BUILDING COMPONENTS

86-2485

Monte Carlo Method of Predicting Sound Pressure Levels in Enclosed Spaces

A. Marshall, J. Gibb

Central Electricity Generating Board, Southampton, England

Rept. No. TP RD/M/1521/N85, 48 pp (1985)
PB86-184033/GAR

KEY WORDS: Enclosures, Rooms, Noise prediction, Monte Carlo method

An existing Monte Carlo ray tracing computer program has been adapted to predict sound pressure levels in rooms with multiple sources of known sound power. Comparisons of the technique are made with existing analytical and empirical calculation methods with satisfactory agreement.

86-2486

Simultaneous Resonances in Non-Linear Structural Vibrations Under Two-Frequency Excitation

R.H. Plaut, N. HaQuang, D.T. Mook

Virginia Polytechnic Institute and State Univ., Blacksburg, VA

J. Sound Vib., 106 (3), pp 361-376 (May 8, 1986)
6 figs, 10 refs

KEY WORDS: Structural members, Resonant response

A system of equations with quadratic and cubic nonlinearities is considered which models structural elements having initial curvature and exhibiting mid-surface stretching during motion. The excitation has two harmonic components. Attention is focused on cases in which two external resonances exist simultaneously. Primary, subharmonic, superharmonic, and combination resonances are included in the eight cases which are analyzed. Quenching occurs for some cases, where the response due to one resonance can be significantly decreased by application of a second harmonic component associated with another resonance. The results are obtained by the method of multiple scales and are presented as frequency-response curves and as plots of modal amplitude versus excitation amplitude.

86-2487

Disturbance Propagation in Structural Networks

A.H. von Flotow

German Space Operations Center, Wessling, Fed. Rep. Germany

J. Sound Vib., 106 (3), pp 433-450 (May 8, 1986)
10 figs, 29 refs

KEY WORDS: Structural members, Periodic structures, Wave propagation

A structural network is taken to be an assemblage of slender structural members connected to

each other at structural junctions. The junctions may include flexible bodies which, in this work, are restricted to those whose dynamics are described by a finite set of ordinary differential equations. A consistent analytical framework is constructed within which descriptions of various member types and junctions can be accommodated. The analysis is set up for computer implementation. Computational examples are used to demonstrate the techniques.

86-2488

Behaviour of Brick Masonry Walls Under Lateral Loading

S.J. Lawrence

Ph.D. Thesis, Univ. of New South Wales, Australia (1984)

KEY WORDS: Walls, Masonry, Panels, Lateral response

This thesis is concerned with the behavior of unreinforced brick masonry wall panels subjected to lateral loading. Single-leaf rectangular panels with uniformly distributed out-of-plane loading and no superimposed vertical loading are considered. Various arrangement of supports on three or four sides are examined, and different configurations of simply supported edges and built-in edges which allow in-plane forces to develop are considered. An essential part of the investigation is a detailed study of the behavior of brick masonry in pure flexure, including the form and extent of random variation in these properties.

86-2489

Coupled Response Spectrum Analysis of Secondary Systems Using Uncoupled Modal Properties

A.K. Gupta, J.-W. Jaw

North Carolina State Univ., Raleigh, NC

Nucl. Engrg. Des., 92 (1), pp 61-68 (Mar 1986) 3 figs, 5 tables, 9 refs

KEY WORDS: Floors, Equipment-structure interaction, Spectrum analysis, Perturbation theory

A method of performing coupled response spectrum analysis of secondary systems is presented. The response spectrum specified at the base of the primary system is used as the input. The complex coupled mode shapes along with frequencies and damping values are calculated using an efficient and accurate perturbation scheme. The new method is applied to a two-degree-of-freedom secondary system coupled with a six-degree-of-freedom secondary system. It is shown that the response values from the present method are in good agreement with those from the

coupled time history analysis. It is concluded that the present method is sufficiently straightforward and efficient, and that it yields accurate response values.

ELECTRIC COMPONENTS

ELECTRONIC COMPONENTS

86-2490

Finite-Element Analysis and Testing of Complex Busbar Structures Under Short-Circuit Conditions

M. Iordanescu, C. Hardy, J. Noutny

Institut de recherche d'Hydro-Quebec, Varennes, Quebec, Canada

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1457-1462, 6 figs, 9 refs

KEY WORDS: Experimental modal analysis, Busboxes, Finite element technique

A general method has been developed for calculating the dynamic stresses and displacements of busbar structures with rigid conductors, under simultaneous-short-circuit conditions with or without rapid reclosing of a fault. Based on a finite-element technique and modal-response superposition, this method can be used to study a complex busbar structure in its entirety, taking into account both the three-dimensional aspect of the structural components and the paths followed by the fault currents. The analytical procedure and the corresponding computer program DYNBUS have been validated by laboratory tests on a low-profile busbar model and by extensive field tests performed on the busbars of a 315 kV substation.

86-2491

Empirical Determination of Damage Threshold for Leadless Chip Carriers on Printed Wiring Boards

E.A. Szymkowiak, H.S. Gruenberger

Westinghouse Electric Corp., Baltimore, MD

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 235-241, 5 figs, 7 refs

KEY WORDS: Circuit boards, Vibration tests, Fatigue life

A simple method is proposed for determining the maximum safe vibration response level for

printed wiring boards (PWB) which contain leadless chip carrier (LCC) devices. A comparison of the proposed failure threshold with vibration results obtained for three LCC-PWB test setups demonstrates the validity of the new method, in which geometric board bending relationships, combined with appropriate random vibration stress formulations, are used to determine a maximum input excitation consistent with reasonable fatigue life.

86-2492

Dynamic Analysis of Electronic Assemblies (For the Purpose of Environmental Stress Screening)

J.G. Schlagheck

Cincinnati Electronics Corp., Cincinnati, OH
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 128-131, 5 figs, 2 refs

KEY WORDS: Electronic instrumentation, Circuit boards, Testing techniques, Screening

The purpose of this paper will illustrate and provide in a tutorial manner the dynamic mathematical solutions to predict the displacement of a printed wiring board and to develop a peaked and/or notched random spectrum utilizing the NAVMAT(P)-9492 spectrum. The resultant or modified spectrum will provide a safe margin as not to overstress or fatigue the assembly undergoing vibration.

86-2493

Establishment of Random Vibration Screening for Fragile Modules

R.G. Lambert

General Electric Co., Utica, NY
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 113-116, 5 figs, 2 tables, 4 refs

KEY WORDS: Electronic instrumentation, Testing techniques, Random vibration, Screening

This paper describes the establishment of a random vibration screen for an electronics assembly in development having a hybrid module piece-part containing fragile elements. The effectiveness of the screen is evaluated using experimental results and closed-form analytical expressions for damage accumulation assessment.

86-2494

Dynamic Performance Analysis and Optimization of Damping Treatments on Printed Circuit Board

Dai De Pei, Hu Xuan Li

Xian Jiaotong Univ., Xian, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1494-1501, 5 figs, 3 tables, 7 refs

KEY WORDS: Experimental modal analysis, Circuit boards, Damping coefficients, Optimization

With an experimental modal analysis method, the dynamic performance of a typical printed circuit board, carried out by additive partial damping layer treatment and boundary damping treatment, is presented. Theoretical analysis and experimental research have been performed on the treatments' optimization of formation, location and damping effect. The maximum resonant response of the printed circuit board is finally reduced to 1:10 of the initial structure by using damping treatments.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

86-2495

Normal-Mode Sound Propagation in an Ocean with Sinusoidal Surface Waves

G.V. Anand, M.K. George

Indian Institute of Science, Bangalore, India
J. Acoust. Soc. Amer., 80 (1), pp 238-243 (July 1986) 2 figs, 6 refs

KEY WORDS: Sound waves, Wave propagation, Ocean

The normal-mode solution to the problem of acoustic wave propagation in an isovelocity ocean with a wavy surface is considered. The surface wave amplitude is assumed to be small compared to the acoustic wavelength, and the method of multiple scales is employed to study the interaction between normal-mode acoustic waves and the surface waves.

86-2496

Nonlinear Acoustic Wave Propagation in Atmosphere

S.I. Hariharan

Univ. of Tennessee, Tullahoma, TN
Rept. No. N86-22309/6/GAR, 28 pp (Oct 1985)
N86-22309/6/GAR

KEY WORDS: Sound waves, Wave propagation

A model problem that simulates an atmospheric acoustic wave propagation situation that is nonlinear is considered. The model is derived from the basic Euler equations for the atmospheric flow and from the regular perturbations for the acoustic part. The nonlinear effects are studied by obtaining two successive linear problems in which the second one involves the solution of the first problem. Well posedness of these problems is discussed and approximations of the radiation boundary conditions that can be used in numerical simulations are presented.

86-2497

Acoustic Emission Signal Analysis. 1975-May 1986 (Citations from the INSPEC: Information Services of the Physics and Engineering Communities Database)

National Technical Information Service, Springfield, VA, 118 pp (May 1986) PB86-867504/GAR

KEY WORDS: Acoustic emission, Signature analysis, Bibliographies

This bibliography contains 245 citations concerning the detection, monitoring, and analysis of acoustic emission signals occurring during evaluation tests of different metals. Innovative methods, instrumentation, and recording devices for acoustic emission analysis; generation and propagation mechanisms of acoustic emissions; and pattern recognition techniques relative to signal classification technology are among the topics discussed. Applications for acoustic emission signal tests are included for electrical and mechanical engineering.

86-2498

Radiation Fields Far from Point or Ring Source on a Rigid Cylindrical Baffle

M. Tohyama

Nippon Telegraph and Telephone Public Corp., Tokyo, Japan

Acustica, 60 (3), pp 230-235 (May 1986) 6 figs, 6 refs

KEY WORDS: Sound waves, Wave radiation, Baffles

Results are shown for calculations of the frequency and directional characteristics of the far fields radiated by a point or a ring source on a rigid cylindrical baffle whose length is infinite. Asymptotic representations of the far fields are used for calculations. The asymptotic forms are obtained using the stationary phase method.

86-2499

High Intensity Acoustic Noise Generation Closed Loop System

J.P. Lee

Scientific-Atlanta, San Diego, CA

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 170-180, 12 figs, 5 refs

KEY WORDS: Acoustic tests, Test facilities, Digital techniques, Computer-aided techniques

An automatic digital control system built for high-intensity acoustic testing is described. System software was designed to simultaneously control up to four acoustic noise generators, each operating in its own frequency range. Test definition, control, and graphics are provided in 1/3, 1/6, full octave, and narrowband formats. The system may be controlled from its own front panel as a stand alone system or from a remote host computer.

86-2500

Propagation of Finite Amplitude Sound Waves Radiated from a Pulsating Sphere

Y. Inoue, S. Ishii, T. Okigami

Osaka Univ., Osaka, Japan

J. Sound Vib., 106 (2), pp 257-265 (Apr 22, 1986) 1 fig, 8 refs

KEY WORDS: Sound waves, Wave propagation

The propagation of weakly nonlinear acoustic waves radiated from a harmonically pulsating sphere in an inviscid perfect gas is studied. A representation of the solution is presented for a far field equation of the first order, which is closely related to the solution obtained by the method of renormalization. The applicability of the method to the present problem is proved within the first order approximation.

86-2501

Excitation of Gas Bubbles for Free Oscillations

K. Vokurka

Czech Technical University, Prague, Czechoslovakia

J. Sound Vib., 106 (2), pp 275-288 (Apr 22, 1986) 11 figs, 26 refs

KEY WORDS: Bubble dynamics, Oscillation

Methods for excitation of gas bubbles into free oscillations are classified and discussed. The analysis is based on Rayleigh's model of a medium-sized bubble. A nonlinear amplitude is

selected to be a universal measure of bubble oscillation intensity and its relation to natural intensity measures is determined.

86-2502

Response and Noise Transmission of Double Wall Circular Plates and Laminated Composite Cylindrical Shells

D.A. Bofilius

Ph.D. Thesis, Columbia Univ., 126 pp (1985)
DA8604596

KEY WORDS: Circular plates, Cylindrical shells, Layered materials, Fiber composites, Noise transmission

An analytical study is presented to predict the response and noise transmission of double wall circular plates and double wall laminated composite fiber reinforced cylindrical shells to random loads. The core of the double wall construction is taken to be soft so that dilatational motions can be modeled. The analysis of laminated shells is simplified by introducing assumptions similar to those in the Donnell-Mushtari theory for isotropic shells. From the parametric study it was found that by proper selection of dynamic parameters, viscoelastic core characteristics and fiber reinforcement orientation, vibration response can be reduced and specific needs of noise attenuation achieved.

SHOCK EXCITATION

86-2503

Frequency Domain Analysis of High Explosive Simulation Technique Fidelity

B.L. Bingham

Applied Res. Assoc., Inc., Albuquerque, NM
Rept. No. DNA-TR-85-149, 132 pp (Mar 30, 1985) AD-A166 106/5/GAR

KEY WORDS: Explosion effects, Simulation, Frequency domain method

The high explosive simulation technique (HEST) is a method of simulating the airblast from a nuclear detonation. HEST cavities are usually designed to match an idealized Speicher-Brode representation of a nuclear airblast overpressure-time waveform, but significant differences often occur. Of particular interest in this report is the high frequency spiking characteristic of HEST cavities and its possible effect upon ground shock and structural response. One product of this work effort was a computer code, FRICQRES, which calculates soil or structural

response due to an ideal Speicher-Brode airblast waveform input. This response to a Speicher-Brode input can then be compared to the measured HEST response to obtain a qualitative indication of the effect of HEST anomalies.

86-2504

Blasting and Blast Effects in Cold Regions. Part 1. Air Blast

M. Mellor

Cold Regions Research and Engineering Lab., Hanover, NH
Rept. No. CRREL-SP-85-25, 68 pp (Dec 1985)
AD-A166 315/2/GAR

KEY WORDS: Air blast, Explosion effects

This report contains the following: ideal blast waves in free air; the shock equations for air blast; scaling procedures for comparison of explosions; reflection and refraction of air blast; effect of charge height, or height of burst; attenuation of air blast and variation of shock front properties; air blast from nuclear explosions; air blast from underground explosions; air blast from underwater explosions; air blast damage criteria; effects of ambient pressure and temperature; explosion in vacuum or in space; air blast attenuation over snow surfaces; shock reflection from snow surfaces; shock velocity over snow; variation of shock pressure with charge height over snow; and release of avalanches by air blast.

86-2505

Analysis and Prediction of Outrunning Ground Motion

S. Hassiotis

Applied Res. Assoc., Inc., Albuquerque, NM
Rept. No. DNA-TR-85-155, 51 pp (Jan 1985)
AD-A166 112/3/GAR

KEY WORDS: Ground shock

With the advent of the hard mobile launcher, the need for an accurate prediction procedure for the outrunning ground shock, i.e., the wave that arrives before the airblast, has increased. Most methods developed in the past for prediction of the outrunning wave concentrate on a limited number of HE experiments. This report describes the development of a new method to predict the outrunning portion of the ground shock. It is based on the empirical analysis of data provided by several recent HE experiments at various heights-of-burst. A characteristic velocity time history waveform, which is normalized by the outrunning velocity peak and a site

dependent time scale factor, is introduced. The method is evaluated against data from several experiments and the results are considered satisfactory.

86-2506

Maribo Structural Response: A Pilot Study

R.B. Burdick, H.J. Weaver, D. Trummer
Lawrence Livermore Nat'l. Lab., CA
Rept. No. UCID-20670, 55 pp (Nov 1985)
DE86007248/GAR

KEY WORDS: Underground explosions, Nuclear explosion effects, Test equipment

The effects that ground motion from underground nuclear tests have on critical testing equipment used in neighboring events often concern Nuclear Test Program personnel. Currently, little is known about the structural amplification that occurs in NTS structures subject to strong base motions. This study seeks to investigate the feasibility of using collected frequency response functions and acceleration data to enable more efficient response predictions.

VIBRATION EXCITATION

86-2507

Dynamic Responses of Structure to Multiple Support Seismic Excitations — A Random Vibration Time History Analysis

G.D. Gazis
Ph.D. Thesis, Univ. of Illinois at Chicago, 234 pp
(1985) DA8602377

KEY WORDS: Seismic response, Supports, Random vibration, Multistory buildings

A modal state space random vibration analysis is presented to obtain the responses of a general multiple-degree-of-freedom (MDOF) system subjected to excitation at multiple support points. The excitation, whether earthquake- or wind-type loading, is modeled as a colored, correlated, vector-valued, nonstationary random process. A new filter is used so that the excitation can have more than one predominant frequency and a wide range of spectral shapes. The time history of the root mean square (RMS) of the earthquake excitation at support points or the wind force at nodal points, which is the output of the filter, is prescribed directly. The corresponding input to the filter, a fictitious piecewise linear strength envelope, is estimated before engaging the filter with the actual system. In addition, for earthquake excitations the filter allows the support

motions to be prescribed in terms of displacement, velocity or acceleration. The time history of the cross correlation between any two components of the excitation can also be prescribed.

86-2508

Earthquake Response of Multi-Degree Nonlinear Structures to Real and Multi-Modal Synthetic Ground Motions

D. Davani
Ph.D. Thesis, George Washington Univ., 191 pp
(1985) DA8604307

KEY WORDS: Seismic response, Multi-degree-of-freedom systems, Energy transfer, Soil-structure interaction, Simulation

A multi-modal analytical scheme is developed that duplicates the time-rate of energy transfer from the ground to the structure, taking into account the frequency content of the structure and time duration of the earthquake. Contrary to the more detailed and sophisticated statistical approaches, this model uses calibration parameters that are developed from power spectral density analysis of the neutral environment of a particular site. This model uses a superposition of several filters to better represent the energy transfer mechanism between the ground and the structure. The proposed model takes explicitly into consideration the effects of the free ground motions but can be easily expanded to include the soil/structure interaction.

MECHANICAL PROPERTIES

DAMPING

86-2509

A Nonlinear Theory of Dynamic Systems With Dry Friction Forces

A.V. Srinivasan, B.N. Cassenti
United Technologies Research Center, East Hartford, CT
J. Engng. Gas Turbines Power, Trans. ASME, 108 (3), pp 525-530 (July 1986) 17 figs, 2 refs

KEY WORDS: Coulomb friction

Structural systems with interfaces where one component may rub against another are not uncommon in aircraft and other engineering structures. The dynamic characteristics of such systems need to be calculated for use in design

and such calculations depend on the law of friction used to represent the interacting boundaries. This paper proposes a nonlocal law of dynamic friction and establishes a procedure to incorporate such laws in a general structural dynamic analysis.

86-2510

Prediction of Total Loss Factor of Structures Part III: Effective Loss Factors in Quasi-Transient Conditions

H.B. Sun, J.C. Sun, E.J. Richards
Univ. of Southampton, Southampton, England
J. Sound Vib., 106 (3), pp 465-479 (May 8, 1986)
15 figs, 13 refs

KEY WORDS: Damping coefficients, Loss factors, Plates

The effective loss factors of coupled structures in quasi-transient conditions are considered which are thought to be important parameters in the prediction of ringing noise radiated from impacting machines. SEA is used and Maidanik's arguments are re-examined in analysis and discussion. A series of measurements have been carried out on two coupled plates (a structure having two substructures) and a randomly chosen complicated structure. An equation derived from the two coupled substructures model is used to estimate the effective loss factors of the two coupled plates. Good agreement is obtained between the estimated and measured values.

86-2511

Improvement and Optimization of Internal Damping of Fiber Reinforced Composite Materials

C.T. Sun
Univ. of Florida, Gainesville, FL
Rept. No. AFOSR-TR-86-0049, 174 pp (Dec 17, 1985) AD-A166 173/5/GAR

KEY WORDS: Fiber composites, Internal damping, Optimization, Material damping, Stiffness coefficients

Analysis of material damping and optimization of both material damping and specific stiffness of laminated, continuous or discontinuous fiber reinforced polymer matrix is the major objective of this study. The analytical solution was achieved by using a force-balanced model to derive the equivalent modulus of unidirectional aligned short fiber composites. Analytical results are compared with those obtained from the classical two-dimensional lamination theory. Sequential simplex method, laminated plate theory, and an elastic-viscoelastic correspondence

principle are used to optimize both material damping and a specific stiffness of composites.

FATIGUE

86-2512

Dynamic Stress Analysis and Fatigue Life Prediction for Structures Subjected to Random Excitations

Fei Guan, Ping Chen
Tsinghua Univ., Beijing, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1558-1563, 6 figs, 10 refs

KEY WORDS: Experimental modal analysis, Fatigue life, Random excitation, Component mode synthesis, Ground vehicles

A general method, based on the methods of component mode synthesis, is presented for calculating the dynamic stress of complex structures subjected to random excitations. From the relationship between the responses and excitations in frequency domain, the spectral density function of response stress can be developed. As an example of the application of this method, the dynamic stress is calculated for the frame of a vehicle moving on a given rough road. A computer program for this method has been proposed. As a practical example, the fatigue life prediction of a vehicle frame is completed using this computer program.

WAVE PROPAGATION

86-2513

Path Integrals for Wave Intensity Fluctuations in Random Media

B.J. Uscinski, C. Macaskill, M. Spivack
Univ. of Cambridge, Cambridge, England
J. Sound Vib., 106 (3), pp 509-528 (May 8, 1986)
6 figs, 12 refs

KEY WORDS: Wave propagation

Approximate expressions for the fourth order moment of a wave propagating in a random medium are derived by using the path integral formulation. These solutions allow the spectrum of intensity fluctuations of a multiple scattered wave to be found, and they are valid at all distances in the medium. The spatial frequency spectra of intensity fluctuations are evaluated for a medium in which the irregularities have a single scale and also for one in which there is a range of scale sizes.

86-2514

Multiple Scattering of Compressional and Shear Waves by Fiber-Reinforced Composite Materials
V.K. Varadan, Y. Ma, V.V. Varadan
Pennsylvania State Univ., University Park, PA
J. Acoust. Soc. Amer., 80 (1), pp 333-339 (July 1986) 13 figs, 1 table, 11 refs

KEY WORDS: Fiber composites, Wave scattering

A multiple scattering formalism using a T matrix to characterize the response of a single fiber to an incident wave is presented to describe P- and SV-wave propagation in a fiber-reinforced composite. A convenient numerical procedure is then developed to compute the effective elastic moduli, attenuation, and phase velocity as a function of frequency and fiber concentration.

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1596-1600, 7 refs

KEY WORDS: Modal analysis, Parameter identification technique, Autoregressive/moving average model

Based on a discrete model of time series, the autocovariance function and the unit impulse response function (Green's function) in time and other domains are applied to transform a discrete model of time series into a corresponding continuous one for modal parameter identification. The relationship between model parameters and modal parameter are deduced. The possibility of identification of all modal parameters using a time series model are discussed.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

86-2515

Response of Structures to Random Excitations in Time Domain

Chang Jiu, Gu Yi
Northwestern Polytechnical Univ., Xian, Shaanxi, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 891-896, 1 fig, 1 table, 8 refs

KEY WORDS: Modal analysis, Random response, Time domain method, Power spectral density

A new and easily used state variable method of structural response analysis to random excitations in the time domain developed and its application is illustrated by two numerical examples. The method readily applies to any type of excitation characterized by power spectral densities. The random excitations can be mathematically matched as the output of a linear system which has a stationary white-noise process as its input. The equations of an augmented system driven by white-noise can then be obtained.

86-2516

On Fitting Continuous Model of the Series for Modal Parameter Identification

Yang Shuzi, Zhao Xing, Wang Zhifan, Yang Kechong
Huazhong Univ. of Science and Technology, Wuhan, China

86-2517

Global Modal Parameter Estimation Methods: An Assessment of Time Versus Frequency Domain Implementation

J. Leuridan, J. Lipkens, H. Van der Auweraer, F. Lembregts
Leuven Measurement & Systems, Leuven, Belgium
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1586-1595, 12 figs, 5 tables, 10 refs

KEY WORDS: Experimental modal analysis, Parameter identification technique, Global identification technique, Frequency domain method, Time domain method

Many new global parameter estimation techniques have been developed over the past few years. Most of these techniques analyze data in the time domain (time domain implementation); fewer are designed to analyze data in the frequency domain (frequency domain implementation). This paper discusses some of the fundamental differences between both kinds of implementations. Cases are discussed to illustrate when a particular implementation is more advisable.

86-2518

A New Cepstrum Technique for Cancelling the Effects of Sound Reflection

Shaoquan Lin, Zhongyi Chen
Tongji Univ., Shanghai, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 936-942, 7 figs, 5 refs

KEY WORDS: Experimental modal analysis, Noise source identification, Measurement techniques, Cepstrum analysis

For correct measurement of an acoustic signal, it is necessary to eliminate the disturbance caused by reflection. In this paper a new cepstrum technique for cancelling the effects of reflection is described. After computer simulations, a series of experiments in an anechoic chamber are carried out. The results of both computer simulations and experiments show the proposed technique is effective.

86-2519

Sound Power Measurement of a Digital Computer Using Surface Velocity

A. Chawla, N. Popplewell

Sperry Inc., Winnipeg, Manitoba, Canada

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 924-929, 3 figs, 5 refs

KEY WORDS: Modal analysis, Computer systems hardware, Sound power levels, Measurement techniques

This paper describes a pragmatic approach for measuring the sound power of a digital computer by using surface velocity measurements. The method is based upon the idealization of the computer as a sphere pulsating in its breathing mode. The practical implications of such an approach are also discussed.

86-2520

Using and Understanding Electrodynamic Shakers in Modal Applications

N.L. Olsen

Hewlett-Packard Co., Everett, WA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1160-1167, 20 figs, 5 refs

KEY WORDS: Experimental modal analysis, Electrodynamic shakers, Test facilities

Electrodynamic shakers are commonly used when acquiring frequency response functions to provide the excitation force during modal testing. Experimental measurement errors attributed to impedance mismatch between the shaker and the structure under test can often be eliminated or significantly reduced by understanding the aspects of armature mass and suspension stiffness effects, back EMF (electromotive force) and current versus voltage amplifiers. Proper choice of the shaker characteristics can often eliminate the need to try alternative methods of computing the frequency response function.

86-2521

Non-Contact Stress Pattern Analysis of Structures Loaded with Complex Waveforms

D.E. Cliver, W.R.S. Webber, J. Gilbey

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1181-1186, 14 figs, 14 refs

KEY WORDS: Experimental modal analysis, Proximity probes, Stress analysis

The stress pattern analysis of structures (SPATE) technique is summarized. Development of the technique for complex mechanical loads which are other than single frequency and uniform amplitude as may exist during in-service or modal analysis loading conditions is described. Some early results are reported from a hole in a steel plate specimen and a beam in bending both excited with pseudo-random load waveforms.

86-2522

Improvement to Monoreference Modal Data by Adding an Oblique Degree of Freedom for the Reference

O. Dossing

Bruel & Kjaer, Denmark

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1175-1180, 13 figs, 2 tables, 4 refs

KEY WORDS: Experimental modal analysis, Testing techniques

In modal testing using monoreference techniques; i.e., the measurement of one row or one column of the frequency response function matrix, careful consideration must be given to the choice of reference degree-of-freedom (DOF). The reference, or driving point, measurement must contain all the modes of vibration in the frequency range of interest, and these should ideally be of equal strength. In this paper a transducer head is presented whereby an oblique DOF can be introduced for the driving point with both ease and precision. Examples are given of the improvements obtained using this as compared to traditional measurement methods. The experiments prove the efficiency of the technique in terms of more accurate modal parameters.

86-2523

Modern Sinusoidal Frequency Response Analysis

R. Lax

Solartron Instruments, Irvine, CA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1445-1449, 6 figs, 4 refs

KEY WORDS: Experimental modal analysis, Vibration tests, Periodic excitation, Testing techniques

The technique of sinewave correlation filtering as applied to the problem of vibration testing is investigated, in particular the accurate and repeatable measurement of transfer function gain and phase as required for modal analysis.

86-2524

Identification of System Physical Parameters from Force Appropriation Technique

M. Thomas, M. Massoud, J.-G. Beliveau
Quebec Industrial Research Center, Canada
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1098-1103, 9 figs, 2 tables, 6 refs

KEY WORDS: Phase methods, Parameter identification technique, Experimental modal analysis

In the area of harmonic excitation techniques for modal analysis, the analyst can use single or multi excitation forces to tune real or complex modes and to measure mobility readings from which modal parameter estimations can be derived. The accuracy of the results depends on the ability of the experimentalist to select the appropriate values of the damped natural frequencies which, in turn, depends on the basic assumptions of the damping mechanism. This paper proposes experimental and analytical procedures based on multi-harmonic excitation of the structure and does not impose any condition on damping.

86-2525

Modal Parameter Estimation Using Difference Equations

B.J. Dobson
Royal Naval Engineering College, Devon, England
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1006-1010, 3 figs, 1 ref

KEY WORDS: Experimental modal analysis, Difference equations, Parameter identification technique

The computation of modal parameters for experimental data may be achieved in many ways; however, the majority of the available methods involve complicated curve fitting routines and interpolation procedures. A technique based upon difference equations is described that eliminates many of the problems associated with current methods. The equations are based upon linear

relationships that enable the direct calculation of the modal parameters for the case of a model containing a general form of hysteretic damping.

86-2526

Development of Uncoupling Technique and its Application

N. Okubo, M. Miyazaki
Carnal Chuo Univ., Tokyo, Japan
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1194-1200, 25 figs, 2 refs

KEY WORDS: Experimental modal analysis, Uncoupling technique, Component mode analysis

With the building block approach, the total dynamic behavior of the system can be predicted from each component's dynamic characteristics which can be individually measured. In some cases, the dynamic characteristics are hard to measure because of difficulty in decomposing it from the system. An uncoupling technique is developed to extract the component's dynamic characteristics based on total behavior of the system which can be measured. The basic theory of this technique is described and confirmed by numerical simulations. The technique is then applied to the actual structure to extract the component's dynamics.

86-2527

"The Mode Synthesis — Weighted Residual Method" for Solving the Dynamic Response of a Multidegree-of-Freedom System

Yin Xuegang, Li Bin
Chongqing Univ., Sichuan, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 870-876, 5 figs, 1 table, 6 refs

KEY WORDS: Modal analysis, Modal synthesis, Weighted residual technique, Multidegree of freedom systems

A new method for solving the dynamic response of a multi-degree-of-freedom system is presented. Three recurrent formulae are derived using the third order spline function as piecewise trial functions in discrete regions of time according to the weighted residual method.

86-2528

Comparison of Some Time Domain System Identification Methods for Free Response Data

J.E. Cooper, J.R. Wright
Queen Mary College, London, England

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 831-836, 6 figs, 9 refs

KEY WORDS: Modal analysis, Parameter identification technique, Time domain method, Least squares method, Correlation techniques

Structural modal parameters may be identified from free decay response data using a number of different time domain methods which make use of multi-degree-of-freedom mathematical models in the form of either a summation of exponential weighted trigonometric functions or an autoregressive difference equation. In this paper the Smith least squares, ordinary least squares, and correlation fit methods are described and compared statistically upon simulated two mode single output data in the presence of measurement noise.

86-2529

Global Parameter Estimation Using Rational Fraction Polynomials

R. Jones, Y. Kobayashi

Hewlett-Packard, Everett, WA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 864-869, 5 figs, 1 table, 3 refs

KEY WORDS: Experimental modal analysis, Parameter identification technique, Global fitting method, Least squares method

Two methods are described to identify global modal parameters from a set of measured frequency response functions. Included is a theoretical development of each approach and a comparison of the results obtained from the analysis of a test structure. Both methods are based on the rational fraction polynomial curve fitter previously presented.

86-2530

Improved Starting Vectors for Subspace Iteration Eigensolution Using Dynamic Condensation

J.C. O'Callahan, R.T.F. Koung, C.-M. Chou

Univ. of Lowell, Lowell, MA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 858-863, 3 tables, 10 refs

KEY WORDS: Experimental modal analysis, Finite element technique, Subspace method, Iteration, Dynamic condensation method

Continuous system can be discretized using finite element techniques to predict their linear struc-

tural response. The subspace iteration procedure provides an efficient method of obtaining eigen-solution of the discretized system matrices. The resulting mode shapes and frequencies can be used in conjunction with experimental and analytical modal analyses and structural modifications to describe the system's dynamic characteristics. The convergence rate of the subspace solutions depends on a linearly independent set of starting vectors and their alignment with the system subspace. This paper proposes a dynamic condensation procedure to transform the original system matrices to a reduced space on which a generalized Jacobi solution is performed.

86-2531

Detection, Identification and Quantification of Nonlinearity in Modal Analysis — A Review

G.R. Tomlinson

Univ. of Manchester, England

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 837-843, 9 figs, 29 refs

KEY WORDS: Experimental modal analysis, Nonlinear response

A brief review of the methods employed in modal testing and analysis for the detection and identification of nonlinearity is presented. Several procedures are described and compared where possible in relation to their range of usefulness, ease of application and quality of results. In addition, the possible direction of future trends for the treatment of nonlinear systems in modal analysis is discussed.

86-2532

Identification of Vibration Parameters Using Nonstationary-Response

Yao Yingxian

Nanjing Aeronautical Institute, Nanjing, China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1601-1608, 5 figs, 2 tables, 5 refs

KEY WORDS: Modal analysis, Parameter identification technique, Time domain method, Cantilevers

Two new time domain methods for identifying vibratory system parameters using nonstationary response signals are presented. Five types of signals can be used by these methods. The algorithms based on difference equations of sampled vibratory systems are described. Proposed data preprocessing procedures can improve

calculation efficiency and reduce required computer memory. The results of applying the methods to a cantilever and a large scale concrete frame have shown considerable effectiveness and improvement in vibratory system identification.

86-2533

A Component Mode Synthesis Method Using the Retransformed Physical Coordinates

E. Imanishi, T. Fujikawa, Y. Hamazaki, H. Zui
Kobe Steel, Ltd, Kobe, Japan
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1609-1614, 6 figs, 4 tables, 8 refs

KEY WORDS: Modal analysis, Component mode synthesis

A new method is proposed for analyzing complex structures by a component mode synthesis method. Mass and stiffness matrices of components are expressed by using unconstrained modes and can be applied for both theoretical and experimental modal analysis. Several numbers of the modal coordinates of each component are retransformed to the physical coordinates of the coupling regions by using normal mode shapes. Therefore, each component can be treated as one of the finite elements in FEM analysis making it possible to connect them to each other or to connect them with nonlinear elements obtained by FEM.

86-2534

Comparison of Modal Test Results from Non-Contacting and Conventional Response Measurements

B.G. Musson, J.R. Stevens
LTV Aerospace and Defense Co., Dallas, TX
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1487-1493, 14 figs, 1 table, 3 refs

KEY WORDS: Experimental modal analysis, Acoustic fatigue, Measuring techniques, Proximity probes, Rectangular plates

A band limited random amplitude acoustic field is used to excite a square, flat plate with clamped edges. Response measurements are made with an accelerometer that is moved from point to point, and measurements of the near field acoustic response are made by moving a microphone from a point to point over the same grid. The accelerometer and microphone are each referenced to a fixed microphone in the acoustic forcing field and modal results are

obtained. Results are compared with analytical solutions and conclusions are presented concerning the use and possible applications of the noncontact measurement method.

86-2535

A New Fibre Optic Sensor for Inprocess Measurement of Machine Tool Vibration

T.I. El-Wardany
Alexandria Univ., Egypt
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1438-1444, 8 figs, 7 refs

KEY WORDS: Experimental modal analysis, Measuring instrumentation, Fiber optics, Detectors, Machine tools

Optical fiber sensors are now introduced in various types of measurement and control techniques. These fiber optics are characterized by features such as wide band width, non-conductivity that eliminates electro-magnetic interference, wideness of linear range, high sensitivity, small sizes, light weight, etc. In this paper fiber optics has been adapted for developing a sensor for determining the relative vibration by measuring the change of the gap length between the fiber optic probe and the workpiece surface as a function of the change of intensity of the reflected beam of light received by the sensor. The simplicity and low cost of the fiber optic set up make it possible to be used as a continuous vibration monitor for assessment of machine tool performance.

86-2536

A Study of Digital Signal Processing Errors Caused by Improper ADC Settings

T.A. Mouch, S. Akers, J. Hicks
Structural Measurement Systems, Inc, Southfield, MI
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1432-1437, 10 figs, 2 tables, 5 refs

KEY WORDS: Experimental modal analysis, Measuring instrumentation, Digital techniques, Signal processing, Error analysis

The effects of digital signal processing errors caused by improper analog to digital conversion settings are discussed. Four signal types are analyzed: overload and underload on the input channel; overload and underload on the response channel. The errors will be shown to affect the quality and accuracy of the measured frequency response function. The errors which are present

in the measurement are also shown to exist as an inaccurate estimate of the modal residue obtained through curvefitting.

86-2537

The New Integral Electronic Microphones & Accelerometers

J.E. Judd

Vibra-Metrics, Inc., Hamden, CT

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 157-162, 13 figs, 2 refs

KEY WORDS: Accelerometers, Measuring instrumentation

Improved noise immunity, high reliability, and more accurate test results are just a few of the advantages offered by these new devices. Equally important is the lower initial system hardware cost and the decreased risk of rapid facility obsolescence. The instrumentation engineer planning a new vibration or acoustic facility should look closely at the new low impedance accelerometers and give careful consideration to their many advantages.

86-2538

Numerical Analysis of Ultrasonic Transducer Vibrations from Optically Measured Beam Profiles

F. Holzer, R. Reibold

Technical Univ. of Graz, Graz, Austria

Acustica, 60 (3), pp 236-243 (May 1986) 6 figs, 5 refs

KEY WORDS: Transducers, Ultrasonic vibrations, Numerical methods

The steady-state, water-loaded vibrational behavior of four plane ultrasonic transducers in the lower MHz range was analyzed by calculating the normal velocity distribution of the transducer surface from the ultrasonic pressure distribution measured in both magnitude and phase in a given cross-section of the beam. The pressure data were obtained by using the light diffraction tomography method, from which the axial component of the particle velocity in the medium can be calculated in any cross-section by a two-dimensional FFT technique. The validity of our numerical method was tested taking the well-known (simulated) case of a circular position radiator.

86-2539

Energy Transfer During Impact Testing

A. Soom, B.-J. Wang, T. Trachsler

State Univ. of New York, Buffalo, NY
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1424-1431, 13 figs, 1 table, 6 refs

KEY WORDS: Experimental modal analysis, Impact tests, Energy transfer, Measuring instrumentation

The quality of measured frequency response functions in vibration testing depends both on the temporal (or frequency) characteristics of the excitation as well as on the response. In this paper the energy transfer to the test structure in both time and frequency domains is generalized in terms of dimensionless pulse duration, peak force, and system response parameters. It is found that excitation and system response can be combined to determine optimal pulses for both single and multi-degree-of-freedom system testing.

86-2540

Transducers and Instrumentation

G. Rasmussen

Bruel & Kjaer, Denmark

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1417-1423, 27 figs, 3 refs

KEY WORDS: Experimental modal analysis, Accelerometers, Mounts, Standards and codes

Measurements on structures are often carried out using accelerometers. ISO has issued a standard, ISO/DIS 5348, covering the mounting of accelerometers. The effect of loading on the structure can be important. The measurement of rotational components is important for the measurement of energy flow in plates. Accelerometers can be calibrated and used for this purpose. On plates and foils, acoustic methods offer great advantages for such measurements. Comparison of acceleration measurements and acoustic pressure measurements shows under the correct circumstances very good agreement.

86-2541

A Digital Data Input Channel for the Multiple Input Multiple Output Environment

D.W. Morton

Hewlett-Packard, Lake Stevens, WA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1410-1416, 5 figs, 7 refs

KEY WORDS: Experimental modal analysis, Measuring instrumentation

An input channel architecture which uses advanced triggering, hardware zoom and FIFO functions to improve versatility and data storage capabilities while allowing real time processing of the data is discussed. This architecture is presented in the context of a large system/MIMO environment, and an implementation using a CMOS chipset is suggested.

86-2542

Computation of Total Response Mode Shapes Using Tuned Frequency Response Functions

R. Brillhart, D.L. Hunt

SDRC, Inc., San Diego, CA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1228-1236, 7 figs, 1 table, 5 refs

KEY WORDS: Experimental modal analysis, Data processing, Mode response on trace method, Mode shapes, Natural frequencies

A new approach which allows rapid computation of mode frequencies and shapes immediately following data acquisition is presented. The technique is applicable to multiple-input modal tests in which frequency response functions are obtained. When this technique was applied to an aerospace structure, the results compared well with the polyreference approach, yielding results in considerably less time with less user interaction.

86-2543

Design of a Highly Interactive Software Environment for Versatile Vibration Testing and Signal Processing on Microcomputers

P. Kopff

Electricite de France

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1156-1159, 5 refs

KEY WORDS: Vibration tests, Signal processing techniques, Experimental modal analysis, Computer programs, Data processing

Specialization of the FORTH language as a control language for unified access to vibrational data acquisition and processing, and to various modal post-processing software tools, is described. To get the best of the particular advantages of the hardware architecture of the host computer and its peripherals, an optimized machine-oriented module communicates with FORTH to take care of basic input-output and most processing inner levels. Apart from this very compact module, and of the kernel of

FORTH (which is very compact too) the whole software might be considered portable.

86-2544

The H_2 Frequency Response Function Estimator

A.L. Wicks, H. Vold

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 897-899, 1 fig, 3 refs

KEY WORDS: Modal analysis, Frequency response function, Coherence function technique, Data processing

The classic model used to estimate the frequency response function from measured data assumes uncorrelated noise operating on the response measurement. Since measurements for both the input or forcing function and the response are commonly made, the classic model ignores the likelihood of noise in the input measurement. An alternative model was developed which considered the uncorrelated noise solely on the input measurement and has been called the H_2 estimator. A more general model may be postulated which acknowledges the presence of uncorrelated noise on both the input and the response measurement. This being the most common case, the estimators H_1 and H_2 contain a bias error resulting from the unaccounted for noise. This paper presents a formulation which accounts for the uncorrelated noise on both the input and the response measurement for the general model.

86-2545

Practical Application of the Modal Confidence Factor to the Polyreference Method

D.L. Hunt, R. Brillhart

SDRC, Inc., San Diego, CA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 900-907, 8 figs, 2 tables, 6 refs

KEY WORDS: Experimental modal analysis, Parameter identification technique, Polyreference method, Modal confidence method, Data processing

The polyreference method estimates modal parameters from sets of frequency response functions referenced to multiple exciter locations. The method requires little user interaction, except in determining the optimum number of poles to use in computing mode shapes. A recent addition to polyreference, the modal confidence factor (MCF) assists the user by assigning a value to each pole, which can quickly allow separation of structural modes from

computational roots. An extension to MCF using the mode indicator function has resulted in a more automated and straightforward approach for determining the optimum number of poles in the analysis.

86-2546

A Comparison of Some Frequency Response Function Measurement Techniques

J. Leuridan, D. De Vis, H. Van der Auweraer, F. Lembregts
Leuven Measurement & Systems, Leuven, Belgium
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 908-918, 13 figs, 2 tables, 14 refs

KEY WORDS: Experimental modal analysis, Frequency response functions, Measurement techniques, Data processing

Recent developments in multiple input measurement technology are reviewed. Several estimation techniques and several excitation methods are discussed. Their influence on the FRF measurements is illustrated with a practical example.

86-2547

Precorrection of On-Line Measured Data and Modal Analysis of Machine Tool Structures

B.H. Lu, Z.H. Lin, C.H. Ku
Xi'an Jiaotong Univ., Xi'an, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 919-923, 10 figs, 1 table, 6 refs

KEY WORDS: Modal analysis, Machine tools, Error analysis, Data processing

The effect of coherent noise on the result of modal analysis is discussed. Based on the theory of multi-input process a formula for measured data precorrection is derived. By such precorrection the bias errors, caused by coherent input noises, can be eliminated and the result of modal analysis becomes more accurate. Good agreement between the prediction of machining chatter during the cutting tests on five lathes has proved the validity of this method.

86-2548

A Rectangular Plate is Proposed as an IES Modal Test Structure

D.O. Smallwood, D.L. Gregory
Sandia National Labs., Albuquerque, NM
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1246-1255, 5 tables

KEY WORDS: Experimental modal analysis, Data processing, Rectangular plates, Test facilities

Numerous modal systems are now marketed by commercial companies and new users are continually being introduced to these systems. A simple test structure would be useful to compare these systems on a common basis. The structure would also provide new users with a means to evaluate their newly acquired experimental and analytical skills. This paper discusses a particular proposed rectangular plate. The physical description of the plate is given, the modal properties of the plate are discussed, and experimental results are given to illustrate the plate behavior.

86-2549

Virtual Coherence: A Digital Signal Processing Technique for Incoherent Source Identification

S.M. Price, R.J. Bernhard
Purdue Univ., West Lafayette, IN
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1256-1262, 21 figs, 9 refs

KEY WORDS: Experimental modal analysis, Data processing, Signal processing techniques, Coherence function technique

The digital signal processing techniques for identification of noise or vibration energy sources; ordinary, multiple and partial coherence techniques, either require incoherence of the measured input data or a degree of a priori knowledge of the system. This paper discusses a transformation technique for conditioning the measured spectra to determine how many real incoherent sources exist and to create a virtual image of those sources at the measurement plane. In addition, the conditioned spectra can be used to generate a virtual coherence function between the measured output and each of the incoherent inputs.

86-2550

A Frequency Domain Holo-Estimation Method of Vibration Parameters

He Hang-An, Jiang Jie-Sheng, Gu Song-Nian
Northwestern Polytechnical Univ., Xi'an, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1263-1267, 4 tables

KEY WORDS: Experimental modal analysis, Data processing, Frequency domain method, Parameter identification technique, Holographic techniques

A new performance index is proposed for identifying parameters of a vibration system. The performance index considers not only the norm but also phase of error vector. A new least squares estimation formula is presented for estimated parameters. Some computational examples from practical systems demonstrate that a notable improvement of vibration parameters estimation is obtained by use of the proposed method.

86-2551

Some Applications of Frequency Domain Polyreference Modal Parameters Identification Method

Lingmi Zhang, Hiroshi Kanda, F. Lembregts
Nanjing Aeronautical Institute, Nanjing, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1237-1245, 17 figs, 11 refs

KEY WORDS: Modal analysis, Parameter identification technique, Multireference method, Finite difference technique, Data processing

This paper describes the utilization of a new multi-input/multi-output modal parameter identification method, which is called the frequency domain polyreference method, and provides some practical applications illustrating the algorithm and features. A comparison with the modern time domain polyreference complex exponential method is presented. The results show that the two polyreference methods have the ability to extract accurate and consistent modal parameters, and to handle very closely spaced modes. Compared to the time domain method, this new technique demonstrates less sensitivity to computational modes, user interaction and judgment.

86-2552

A New Development on Transfer Function Fitting

Huang Dun-Pu, Liu Man
Changchun Automobile Research Institute, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1359-1366, 3 tables, 3 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test, Transfer functions, Linearization methods, Automobiles

A successive linearization method which is principally derived from the linear optimization theory has been developed which can be used in the process of transfer function fitting to improve its accuracy. The method and its principle

of transfer function fitting on frequency division are presented. Test data and analytical values obtained indicate that the transfer function calculated by means of the software developed in this paper is quite accurate.

86-2553

Modal Analysis of a Two Axis Gimbal: Finite Element Model vs Test Results

J.D. Getber
Ball Aerospace Systems Division, Boulder, CO
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1352-1358, 3 figs, 5 tables, 2 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test, Gimbals, Spacecraft components, Finite element technique

The primary resonances and mode shapes of a spacecraft two axis gimbal were evaluated with a NASTRAN finite element model solution and compared with extensive test results. Test results were obtained from .05g and .25g sine sweeps as well as exciting resonance by dithering the gimbal drive motors. Results showed excellent correlation between analysis and data on the first four modes.

86-2554

Critical Application of the Error Matrix Method for Localisation of Finite Element Modeling Inaccuracies

H. Gysin
Swiss Fed. Institute of Technology, Zurich, Switzerland
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1339-1351, 19 figs, 2 tables, 7 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test, Error analysis, Matrix reduction methods

With the error matrix method it should be possible to locate stiffness respectively mass matrix differences between a finite element calculation and a modal analysis measurement. The method was tested on a 9 degrees-of-freedom spring-mass-system and on a bending beam. Three different reduction techniques were tested on the spring-mass-system. The results of these examples show that the efficiency of the error matrix method depends very much on the type of matrix reduction and on the number of modes used to build up the error matrix.

86-2555

Modal Survey Test of the Oriented Scintillation Spectrometer Experiment

D.W. Paule

Ball Aerospace Systems Division, Boulder, CO
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1335-1338, 3 figs, 3 tables, 2 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test

This paper describes the modal survey test and the revision to the mathematical model associated with it. Some of the more important modeling features are discussed.

86-2556

Model Refinement Using Test Data

B.P. Wang, T.-Y. Chen, F.H. Chu

Univ. of Texas, Arlington, TX

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1052-1057, 2 figs, 1 table, 6 refs

KEY WORDS: Experimental modal analysis, Linking analysis and test

To improve the test/analytical data correlation, various methods have been developed to correct the stiffness matrix and/or the mass matrix of the finite element models using modal test data. In this paper some of the methods in the literatures are tested with a sample problem to show the effectiveness of the various methods. Discussions and comparisons of these methods are given.

86-2557

Rigid Body Mode Enhancement and Rotational DOF Estimation for Experimental Modal Analysis

M. Furusawa, T. Tominaga

Yamaha Motor Co., Ltd., Shizuoka-ken, Japan
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1149-1155, 14 figs, 3 tables, 3 refs

KEY WORDS: Experimental modal analysis, Computer programs, Constraint modes method, Least squares method, Rigid body modes

This paper presents the theory of rigid body mode enhancement using constraint equations and least squares solution techniques for experimental modal analysis. It examines some of the applications and advantages, especially for the estimation of rotational degree-of-freedom, and presents examples illustrating its usage.

86-2558

Software Architecture for a Multiple Input/Output Dynamic Signal Analyzer

T. Kraemer

Hewlett-Packard, Lake Stevens, WA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1126-1131, 2 figs, 5 refs

KEY WORDS: Frequency response functions, Computer programs, Signature analysis, Multi-point excitation technique, Experimental modal analysis

A multiple input/output frequency response measurement is used to illustrate a proposed software architecture for a general purpose dynamic signal analyzer instrument. The system described is object-oriented rather than procedure-oriented or menu based. This approach results in a more reliable and flexible software system. Application to modal analysis and general signal analysis is described.

86-2559

A Microcomputer Based System for Measuring Natural Frequencies and Mode Shapes of Structures

D.K. Rao

Materials Laboratory, Wright-Patterson AFB, OH
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1117-1125, 15 figs, 13 refs

KEY WORDS: Natural frequencies, Mode shapes, Frequency response functions, Loss factors, Computer programs

This paper describes the application of microcomputers to measure natural frequencies and mode shapes, as well as frequency response functions and loss factors of structures. The developed software, mostly written in a high level language, has two segments. The first segment, called STEPSINE, excites the structure over a specified frequency range in specified frequency increments. The second segment of the software, called MIP (modal image processor) measures and displays the mode shape on-line.

86-2560

Investigating into the Effective Use of Structural Modification

S.C. Ulm

General Electric CAE International, Inc., Milford, OH

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1279-1286, 2 figs, 6 tables, 7 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques

Structural modification is growing in importance in the modal analysis arena, particularly in troubleshooting applications. Unfortunately, since it is a relatively new technique, there is a lack of general understanding and practical experience with its application. This paper addresses these issues by evaluating the accuracy of structural modification relative to errors and deficiencies of typical modal data. The studies evaluate the effects of important potential errors with structural modification including: modal truncation, the lack of rotational degrees-of-freedom in the modal model, and the effect of inaccuracies in mode shape coefficients.

86-2561

The Estimation of Rigid Body Mode Shapes for Use with Structural Dynamics Modification

D.J. Macioce

Structural Measurement Systems, San Jose, CA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1287-1291, 2 figs, 5 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Rigid body modes, Computer programs

A structure which is dynamically modeled or tested in an unconstrained configuration contains up to six rigid body modes of vibration. Finite element analysis methods can easily compute these modes; however, when using experimental modal analysis to characterize the dynamic properties of a structure, the rigid body modes of vibration are typically not measured. Since these modes contain the inertial information of the structure, they are essential when joining two unconstrained substructures together, or to accurately reconstruct a frequency response function. This paper describes a method for estimating these rigid body modes using only the structural geometry and an estimate of the lumped mass distribution of the structure. The results of a computer program which was developed to estimate the rigid body mode shapes is presented along with test cases to demonstrate the use of the method.

86-2562

A Perturbation Method for the Complex Mode Theory of Linear Non-Conservative Dynamic Systems

Zheng Zhao-chang, Tan Ming-yi
Tsinghua Univ., Beijing, China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1292-1298, 3 tables, 16 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Perturbation theory

The second order system of linear nonconservative dynamic equations cannot be decoupled by real mode theory unless some conditions are satisfied. The conventional method used in this case is so called complex mode theory in state space, but is it rather complicated and uneconomical in practical problems. In this paper, the perturbation method based on the real mode theory is utilized to solve the complex eigenpairs of such systems.

86-2563

Determination of Optimal Design Modifications Using Experimental Modal Parameters

P. Gudmundson

Tre Konsulter AB (3K), Vaxholm, Sweden

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1299-1304, 7 figs, 6 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques

Experimentally measured modal parameters are used as input data for the optimization technique described in this paper. The present method predicts the structural modifications necessary to achieve desired changes in eigenfrequencies of a structure. The determined modifications are optimal in the sense that an objective function is minimized. Since the theory is based on sensitivity analysis the size of the considered modifications is limited to approximately ten percent. The use of the method is illustrated by three examples.

86-2564

Effect of Boundary Conditions on the Response of a Structure

M.S. Hundai

Univ. of Vermont, Burlington, VT

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1476-1481, 9 figs, 1 table, 11 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Boundary condition effects, Finite element technique, Natural frequencies

Among the input data for the finite element model of a structure, boundary conditions are most difficult to quantify precisely. These are also potentially the source of significant errors in the results. This paper discusses the finite element modeling and experimental modal analysis of a simple structure. The effect of boundary conditions used in the FEM model on the natural frequencies is investigated.

86-2565

Structural Modifications Using Active and Passive Structural Elements

G.D. Shepard, J.C. O'Callahan, P. Avitabile
Univ. of Lowell, Lowell, MA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1187-1193, 7 figs, 7 refs

KEY WORDS: Structural modification techniques, Experimental modal analysis

Structural modifications to a complex system can be separated into two types -- active and passive modifications. Passive modification refers to the addition of passive structural elements such as beams and plates which have mass, damping and stiffness properties. Active modification refers to the addition of active structural elements such as actuators driven by electronic systems and feedback control signals. In the common application where a structure is to be positioned by a high speed actuator, both active and passive structural elements may be utilized to improve system performance. As an example, a structural system is evaluated using an experimental modal data base and a large order system model which is reduced to an equivalent system suitable for experimental modal model comparision and model improvement using passive structural elements.

86-2566

Combination of Structural Modification Techniques and Acoustic Radiation Models

P. Van de Ponsele, P. Sas, R. Snoeys
Kath. Univ., Leuven, Belgium
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 943-951, 5 figs, 4 tables, 11 refs

KEY WORDS: Modal analysis, Structural modification techniques, Sound waves, Wave radiation

Using modal analysis techniques in combination with local structural modification techniques makes it possible to estimate the shifts in the dynamic properties due to local modifications of

the structure, and consequently they result in a decreased number of prototypes needed for design purposes, thereby generating a serious profit for the user. It is, however, not possible to estimate the impact of such modification on the sound power generated by the structure. This paper deals with a sound optimization strategy where this link is realized. The paper reviews the strategy of the implemented method and reports in detail on the results of calculations and measurements.

86-2567

Modal Control of Flexible Structures Using Modal Residualization Technique

Chang Jin, Gu Yi
Northwestern Polytechnical Univ., Xi'an, China
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1653-1658, 3 figs, 8 refs

KEY WORDS: Experimental modal analysis, Modal control technique, Structural modification techniques, Elastic systems, Modal residualization technique

A new method of modal residualization is presented. It is based on a closed-loop model and can reduce the order of a structure by using a minimization procedure to search for the parameters of the reduced model. This procedure minimizes the deviations of transfer matrix of the reduced model from the transfer matrix of the structure. The control law of the structure is synthesized by using the optimal quadratic theory; the outputs of the reduced model with practical control law then approximate the outputs of the structural system with optimal control law.

86-2568

On Changing Boundary Conditions in Structural Dynamics

B.P. Wang, F.H. Chu
Univ. of Texas, Arlington, TX
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1547-1552, 4 figs, 2 tables, 5 refs

KEY WORDS: Experimental modal analysis, Boundary condition effects, Structural modification techniques

Efficient formulations of computing the eigenvalues and forced harmonic responses of a system with boundary condition changes are developed. This is accomplished by using the modal information of the original structure and reanalysis

formulation. The boundary condition changes considered include addition of rigid or elastic restraints, removal of restraints as well as change of rigid supports to elastic supports. Two numerical examples are included to illustrate the formulation.

86-2569

Bond-Graph Modelling — A New Approach to the Structural Dynamics Problem

P.K. Sen, D. Chandra

Engg. Services Intl. Private Limited, Calcutta, India

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1564-1571, 12 figs, 6 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Bond graph technique, Mathematical models

Bond-graph modeling is one of the several methods of modeling possible for a dynamic system. A bond-graph depicts salient aspects of a time-dependent system having discrete elements, such as mass, spring, dashpot, etc., in a conventional manner using only a few characteristic elements. This paper shows how the bond-graph technique can be applied to solve problems involving dynamical behavior of structures encountered in civil engineering. To show the versatility and generality of bond-graph, a typical problem of biomechanics has also been adopted and solved by this method.

86-2570

Active Structural Modification Using Multivariable Feedback Design Technique

G.D. Shepard

Univ. of Lowell, Lowell, MA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1636-1639, 3 figs, 8 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Active structural modification

Design of actuated structures requires the simultaneous consideration of structural modification, both active and passive, and feedback control. To aid this design process a design approach is presented which combines the efficient matrix techniques used by structural dynamicists with feedback design techniques taken from the field of automatic control.

86-2571

Optimal Redesign of Dynamic Structures Via Sequential Linear Programming

K.B. Lim, J.L. Junkins

Virginia Polytechnic Institute and State Univ., Blacksburg, VA

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1615-1620, 3 tables, 6 refs

KEY WORDS: Modal analysis, Structural modification techniques, Linear programming, Optimization

A sequential linear programming approach for optimal placement/constrained optimization of eigenvalues and eigenvectors of linear dynamical systems is presented. As an example, the total mass of a structure is minimized while the natural frequencies for selected modes are gradually driven to desired values. The above approach appears computationally suitable for redesign of high-dimensioned, complex dynamical systems. Numerical examples are included to demonstrate the practical merit of this approach.

86-2572

An Investigation of Structural Modification Using an H-Frame Structure

S.M. Crowley, M. Javidinejad, D.L. Brown

Structural Dynamics Research Corp., Milford, OH

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1268-1278, 20 figs, 4 tables, 9 refs

KEY WORDS: Experimental modal analysis, Structural modification techniques, Frames

Improvements in data acquisition and modal parameter extraction techniques in recent years, have led to a renewed interest in using a modal model to predict the behavior of a structure subjected to design changes. The ability to quickly evaluate the feasibility of a minor modification to a structure by using a modal database can be quite beneficial. This paper examines the use of structural modification to predict the results of a simple mass and stiffness modification to an H-FRAME structure. Several aspects of the analysis procedure are investigated including the building of an accurate modal model, the contribution of rotational degrees-of-freedom, and the effects of inaccuracies in the estimation of mode shape coefficients on the outcome of a structural modification.

DYNAMIC TESTS

86-2573

Data Acquisition/Control/Analysis Systems for Large-Scale Acoustic Testing Facilities

S. Smith

Lockheed Palo Alto Res. Lab., Palo Alto, CA
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 163-169, 1 fig, 2 refs

KEY WORDS: Acoustic tests, Test facilities

A new generation of computerized data acquisition systems has been developed that provides practical solutions for the needs of large scale acoustic testing facilities. A system that acquires 200 channels with a data bandwidth of 12 kHz for six minutes has been built and is operational. Advances in hardware design in the areas of large, low cost, removable-media disks and digitally-oriented data acquisition front ends will make these systems less expensive and more flexible in the next few years.

86-2574

Martin Marietta Aerospace New High Intensity Acoustic Test Facility

S.M. Rossi

Martin Marietta Denver Aerospace, Denver, CO
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 152-154, 5 figs, 1 table

KEY WORDS: Acoustic tests, Test facilities, Spacecraft, Space shuttles

This paper describes a new high intensity acoustic test facility to meet the needs of system level acoustic testing for shuttle payloads. The features and design considerations of the facility, as well as measured facility performance, are presented.

86-2575

Design and Performance of a Low Cost Vibration Test Facility

S.M. Rossi, J.F. Barthell

Engineering Dynamics, Inc., Englewood, CO
"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 386-391, 3 figs, 1 table

KEY WORDS: Vibration tests, Test facilities, Shakers

An inexpensive design of a complete hydraulic shaker table control and testing system is presented. The shaker table is a single axis system which may be configured to provide excitation along three orthogonal axes. The test table excitation includes user definable test sequences in addition to pre-programmed inputs including swept sine, damped sine, random and shock. The test system was designed and constructed with commercially available hardware components.

86-2576

An Implemented Approach to Host Computer Control (HCC) of a Digital Random Vibration Control System

E.A. Andress

Scientific-Atlanta, Inc., San Diego, CA
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 338-345, 4 figs

KEY WORDS: Testing techniques, Vibration tests, Shakers, Computer-aided techniques, Vibration control

An implemented approach to host computer control of a digital random vibration control system's CPU via RS-232 is discussed. A simplified format permitting the host to download instructions, react to responses from the system, and call for and accept/store selected test data from the slave system, is shown.

86-2577

Personal Computers in Environmental Test Laboratories — In Perspective

D.B. Page

Hughes Aircraft Co., El Segundo, CA
"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 469-472, 5 refs

KEY WORDS: Vibration tests, Personal computers

Personal computers (PCs) are appearing in more and more applications supporting environmental test laboratories. Connected to data loggers, controllers, voice synthesizers, spectrum analyzers, and other instruments, PCs analyze data, monitor alarm limits, and control tests. This paper puts the application of PCs to environmental test labs in perspective. Results from a small survey of PC users are annotated by the author's experiences. Applications, system costs, user experiences, unexpected benefits, safety, and other subjects are discussed.

86-2578

Updating Rail Impact Test Methods

R.A. McKinnon

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 254-262, 5 figs, 2 tables, 10 refs

KEY WORDS: Testing techniques, Impact tests, Railroad trains

The primary objective of this study was to develop a realistic and repeatable method for conducting rail impact tests. This was due to the existence of several different methods plus the need for repeatable results. This new procedure was developed by examining existing rail impact test procedures, analyzing their purposes, and reviewing actual railroad procedures. All of the variables were taken into account individually and collectively and were examined.

86-2579

A Proposed Technique for Ground Vehicle Loose Cargo Vibration Simulation

W.H. Connon, III

U.S. Army Combat System Test Activity, Aberdeen Proving Ground, MD

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 242-253, 12 figs, 11 tables, 12 refs

KEY WORDS: Testing techniques, Vibration tests, Cargo transportation, Simulation, Military vehicles

A technique is described for measuring the actual field environment for loose cargo transported in various military ground vehicles and developing a procedure for realistic laboratory simulation of this environment.

86-2580

A Multiexciter Dynamic-Testing Control, Data-Acquisition, and Analysis System for Railroad Vehicle Evaluation and Environmental Simulation

L. Cackovic, F. Irani, P. Welik

Assoc. of American Railroads, Pueblo, CO

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 363-367, 5 figs

KEY WORDS: Railroad cars, Test facilities

In Pueblo, Colorado, the Association of American Railroads (AAR) Transportation Test Center (TTC) boasts a unique testing facility. This is

the Vibration Test Unit (VTU). It is located in the test center's Rail Dynamic Laboratory (RDL). Dynamic tests on railroad vehicles for environmental simulations and for vehicle evaluations can be performed with the VTU. These tests are done utilizing the VTU's twelve hydraulic actuators (eight vertical and four lateral). The VTU Control System (VTUCS), designed by Synergistic Technology Incorporated (STI) provides the VTU with command-generation, data acquisition, and analysis capabilities. This system allows AAR engineers to perform a wide variety of tests which are needed to help continue the advancement of railroad technology. This paper presents a description of a vibration test unit and its control system, as well as a typical VTU test sequence. Discussed are the mechanical and electrical components of the VTU; the VTU control system hardware design, software design, and performance; and VTU test procedures, data acquisition, and analysis.

86-2581

Swept Sine on Random Testing Using Swept Sampling Rates

J.M. Cies

Hewlett-Packard Co., Paramus, NJ

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 346-352, 6 figs, 1 table, 5 refs

KEY WORDS: Vibration tests, Random vibrations, Testing techniques, Swept sine-wave excitation

A simpler approach to swept sine on random (SSOR) and swept narrow band random on random (SNBROR) vibration testing is proposed. Both SSOR and SNBROR are used to represent the combined effects of random vibration and strong periodic excitation. The key to this method involves varying the sample rate of the analog to digital converter which in turn sweeps the entire frequency band of the test spectrum. The currently available approaches to satisfying this test requirement are summarized and compared to the proposed method. Considerations involved in setting up a test as well as optimizing the control strategy are detailed.

86-2582

Automated MTBF Test System

C.B. Hoskins, V.M. Stone

Naval Weapons Ctr., China Lake, CA

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 330-337, 4 figs, 4 tables

KEY WORDS: Test facilities, Computer aided techniques, Microcomputers

This paper describes an approach taken to automate combined environment reliability testing through the use of a full-time supervisory microcomputer control system.

86-2583

Two Input-Single Output Simulation

R.G. Merritt

Naval Weapons Ctr., China Lake, CA

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 275-294, 20 figs, 3 refs

KEY WORDS: Random response, Testing techniques, Simulation

Several aspects of laboratory simulation of field measured responses based upon a model framework where the field and laboratory models are dissimilar are examined. The model dissimilarity plays a major role in how well the laboratory model can be fit to the field measured model. In general, locally optimum model fits can be found but these fits may not be able to faithfully reproduce the field measurements in the laboratory. Laboratory simulation must be used with care and limitations in the reproduction of field measured environments recognized.

86-2584

Equivalence of Fatigue Damage Caused by Vibrations

J. De Winne

Atomic Energy Commission

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 227-234, 10 figs, 1 ref

KEY WORDS: Swept sine wave excitation, Random tests, Fatigue tests

Materials are subjected in their real environment to vibrations of various kinds (random or sinusoidal) and different types of mechanical shocks. During the design development of a product, it may be necessary to compare the effects of different kinds of vibration on the material. In this paper an experimental validation of a method of determining equivalence (fatigue damage spectra) between swept sine and random vibration tests on circuit boards using various types of technology is proposed.

86-2585

Some Thoughts on the Vibration Testing of Helicopter Equipment in the UK

J.C. Barker, H. Goldberg

Westland Helicopters, Somerset, England

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 420-430, 11 figs, 1 ref

KEY WORDS: Vibration tests, Testing techniques, Helicopter equipment

The paper gives a condensed history of airworthiness requirements in the United Kingdom and briefly describes the helicopter's vibration sources and environment. It also covers the results of a data survey, discusses the issues involved, and offers a description of possible procedures with examples of their use.

86-2586

C.A. Fixture Design

E. Elmalah

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 416-419, 4 figs, 38 refs

KEY WORDS: Vibration tests, Testing instrumentation, Computer programs, Design techniques

The goal of this article is to encourage the use of standard computer codes used in mechanical design to improve fixture design and lead to savings in time and money. An example is included which compares designs by traditional methods and design and analysis using the SAP6-3 code. Natural frequencies, mode shapes and excitation responses are determined. Several design improvements are presented.

86-2587

Computer Aided Vibration Testing Program Design

Z. Sherf, J. Zelicovici, E. Katz, E. Elmalah
Ada-Rafael, Haifa, Israel

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 411-415, 7 figs, 3 refs

KEY WORDS: Vibration tests, Testing techniques, Computer programs

Accurate simulation of the vibration environment of military equipment necessitates measurement and analysis of the environment and conversion

of the analysis results into a vibration simulation program. The paper presents a computer code written to simplify the construction of testing programs. Included are the principles on which the program is based and a description of the program structure and operation mode. Examples of the different options of the program are presented: building of a stationary testing program, of a non-stationary testing program and evaluation of the program with respect to the real environment using extremum statistics and fatigue damage analysis.

86-2588

An Implementation of a Taped Random Vibration System for CERT

E.A. Szymkowiak

Westinghouse Electric Corp., Baltimore, MD
"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 524-527, 4 figs, 1 table, 2 refs

KEY WORDS: Vibration tests, Random vibration, Test facilities

Development and usage of a taped random vibration system as applied to a CERT facility are described. The need to consider spectrum repeatability, product safety, and matching of thermal history are emphasized. Results for a number of boundary conditions are presented.

86-2589

Laboratory Simulation of Field Measured Environments

R.G. Merritt

Naval Weapons Ctr., China Lake, CA
"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 512-523, 9 figs, 1 ref

KEY WORDS: Vibration tests, Simulation

Frequently field measured mechanical vibration environments must be simulated in the laboratory. The laboratory inputs causing the vibration response are often dissimilar from those measured in the field. This paper considers the laboratory simulation of a field measured vibration environment that can be modeled as a two input/single output model. The laboratory simulated inputs are assumed to be dissimilar from those in the field. A rationale for judging the effectiveness of the simulation at the output point is provided.

86-2590

A Dual-Shaker Random Vibration Testing Control System

D. Lehmann

ADA-RAFAEL, Haifa, Israel

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 507-511, 8 figs, 4 refs

KEY WORDS: Shakers, Vibration tests, Random vibration, Computer aided techniques

Special vibration testing problems such as large system testing led to the necessity for dual-shaker testing. Advanced vibration testing systems are controlled with the aid of mini-computers. A special control algorithm was implemented on existing hardware. The algorithm uses a pre-calculated compensation matrix to correct the drive signals which are applied to the shaker amplifiers. This method thus enables the simultaneous operation of the two shakers within the required testing specifications.

86-2591

Closed-Loop Digital Control of Multiaxis Vibration Testing

G.A. Hamma, R.C. Stroud

Synergistic Technology Inc., Cupertino, CA
"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 501-506, 9 figs, 2 refs

KEY WORDS: Vibration tests, Digital techniques

This paper describes the application of multi-excitation closed-loop control systems to multi-excitation sinewave-vibration testing. When the exciters are arranged to be mutually perpendicular, spatial as well as frequency sweeps are achievable. Objectives and results of early applications are compared.

86-2592

Method for Establishing Specifications from Real Environment

J. De Winne

Atomic Energy Commission

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 458-468, 14 figs, 2 refs

KEY WORDS: Specifications, Shock tests, Vibration tests

In their real environment, materials are subjected to a variety of mechanical shocks and vibrations. A method is proposed for establishing simple specifications, possibly of reduced duration, with the same severity as in a complex vibratory environment made up of vibrations of different origins, or of mechanical shocks to which the material is subjected in the course of its working lifetime. The experimental work undertaken to validate the criterion of equivalence between real environment and specifications that was chosen is described.

86-2593

The Comprehension and Use of MIL-STD-810D
Z. Sherf, M. Shaked, G. Ostrovski, E. Elmalah
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 268-274, 16 figs, 8 refs

KEY WORDS: Vibration tests, Military standards

MIL-STD-810D, which replaced 810-C in July 1983, constitutes the basis for important conceptual changes in the planning and performance of environmental testing. Implementation of the new standard is strongly influenced by its interpretation. The paper presents the interpretation given in the author's laboratory to the new standard. Implementation of the new concepts is exemplified in the planning of the vibration testing program for air (unmanned aeroplane) and ground (special trailer) transported systems. The examples stress the use of tailoring concepts (the use of data measured for the systems in their operating environment and for similar systems or similar conditions).

86-2594

Vibration Response on Assemblies or Components in a Excited System

M.B. Dumelin
Defence Technology and Procurement Agency, Switzerland
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 224-226, 6 figs

KEY WORDS: Testing techniques, Standards and codes

The possible differences are shown which may exist between standards, customer-specification and actual measurements as the test spectrum for an entire system. The behavior of rigidly mounted assemblies or items is illustrated. It is

explained that the response values may be up to 15 times the input value. Other examples show the reaction of an assembly mounted on shock absorbers. Experience indicates that there is a typical behavior for such setups.

86-2595

Variable Rate Gunfire Vibration Testing on a Digital Vibration Control System

J.M. Cies

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.", Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 491-494, 6 figs, table, 1 ref

KEY WORDS: Vibration tests, Digital techniques, Gunfire effects

Test specifications that define a line spectrum, such as gunfire spectra, are a perfect match for digital vibration control systems. A limitation is encountered, however, when it is desired to simulate the variation of the firing rate over a narrow frequency band caused by the nonconstant rotating speed of the gun barrels. A technique has been implemented that overcomes this limitation by fooling the control system into seemingly performing a constant rate test when in reality the fundamental frequency and all harmonics are being swept over a narrow frequency band. The focus of this effort is to further describe the details of this method.

86-2596

Accelerometers for Pyroshock Measurements

J.S. Wilson, Tustin Institute of Technology, Santa Barbara, CA
"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 263-267, 1 table, 8 refs

KEY WORDS: Accelerometers, Pyrotechnic shock environment

Unique characteristics which make accelerometer measurements of pyroshock difficult are discussed. Accelerometer characteristics of special concern when measuring pyroshock are enumerated. Recommendations for accelerometer performance specifications for pyroshock are presented. Tabulated results of a survey of available accelerometers are shown.

86-2597

Back to Basics about the Original Meaning of Vibration-Tests

K.-H. Hansen

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 431-434, 9 figs

KEY WORDS: Vibration tests, Shock tests, Fatigue life, Strains

Today's environmental engineering uses many specifications for vibration tests and shock tests. They are written mainly in terms of acceleration and frequency (sine-testing) or acceleration density and frequency spectra (random vibration testing). Shock tests are written usually in terms of maximum acceleration and time history of the shocks (pulse shape). In addition, shock spectra may help to describe these tests in more detail. However, it is not the acceleration, but stress which causes fatigue in materials. To understand the specifications and their implications for a test object, we must think in terms of stress and strain - namely in terms of their peak probability distributions.

86-2598

Development of a Personal Computer Based Data Acquisition and Analysis System for Shock Testing

D.P. Roach

Sandia National Labs., Albuquerque, NM

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 318-329, 16 figs, 11 refs

KEY WORDS: Shock tests, Computer aided techniques, Personal computers, Testing techniques

This paper discusses a specialized use of personal computers in the environmental test lab to accommodate the following needs: provide low cost data acquisition and analysis capabilities for shock testing; allow shock testing in remote test areas; and develop experimental methods which take advantage of the expanding personal computer technology.

86-2599

An On-Line Implementation of MIL-STD-810D Transportation, Helicopter and Gunfire Simulation

A.C. Keller

Scientific-Atlanta, Inc., San Diego, CA

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 353-362, 16 figs, 4 refs

KEY WORDS: Testing techniques, Computer aided techniques, Computer programs, Helicopter vibration, Gunfire effects

A software package entitled ATAGS+ has been developed which is designed to operate on a digital vibration control system. It simulated virtually all of the test methods outlined in MIL-STD-810D including transportation, helicopter, propeller, gunfire, external stores, burn-in and others. Examples of the use of this software are given together with comments on several aspects of control strategies.

86-2600

Characterization of Nonstationary Random Processes

T.L. Paez

Sandia Natl. Labs., Albuquerque, NM

"Improve Your Odds With Sound Basic Sci. and Creative Engrg.," Proc. 31st Ann. Tech. Mtg., Inst. of Env. Sci., Las Vegas, NV, Apr 30-May 2, 1985, pp 495-500, 8 figs, 3 tables, 4 refs

KEY WORDS: Shock tests, Random excitation, Stochastic processes

Current methods for shock test specification and shock testing treat the shock environment as a deterministic source. The present study proposes to treat shock sources as nonstationary random processes. A model for a realistic nonstationary random process shock source is specified, and the effect of variation of parameters in the shock source is shown. A method for estimating the parameters of the random process is established, and some numerical examples show that the method yields reasonable results. The use of this model in shock testing is discussed.

86-2601

Minimum Drive Requirements for a Multiple Input Output Linear System

D.O. Smallwood, T.D. Woodall, E.J. Buksa

Sandia Natl. Labs., Albuquerque, NM

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 295-301, 4 figs, 5 refs

KEY WORDS: Shakers, Test facilities, Random vibration tests

The application of multiple random inputs used to drive a single test item in vibration tests is becoming more common. A test of this nature requires the complete specification of the cross spectral density matrix of all the control points.

If the cross spectra are not specified, they can be chosen to minimize the drive requirements for the test. A set of control point cross-spectra are derived which will minimize the total drive power. The result has a more general application for any linear system with N inputs and N responses. If the auto (power) spectra of the N responses are specified, a set of response cross-spectra which will minimize or maximize the total input power are derived. The method has also been extended to include sine inputs where the desire is to maximize or minimize the drive power while maintaining the input motion at specified amplitudes. The method has been implemented on Sandia's multiple input random vibration control system.

SCALING AND MODELING

86-2602

On the Dynamic Similitude Laws in Vibrational Modal Analysis of Structures

Li Dabao

Tsinghua Univ., Beijing, China

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1582-1585, 2 refs

KEY WORDS: Experimental modal analysis, Simulation, Scaling

In order to ensure the quality of the dynamic behavior of a large structure, it is advisable to identify the modal parameters of its scale model in advance. Using prediction equations the measured quantities carried on the model are converted to that of prototype and the dynamic behavior of the real structure are predicted. This paper gives a brief review of dynamic similitude principles. The main purpose is to derive the design equations and the prediction equations of the scaled model used in vibrational modal analysis. The conversion relationships of the modal parameters between model and prototype are deduced.

DIAGNOSTICS

86-2603

Eigenparameter Analysis of Beams with Different End Conditions

M.M.F. Yuen

Univ. of Hong Kong, Hong Kong

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1572-1576, 8 figs, 12 refs

KEY WORDS: Diagnostic techniques, Experimental modal analysis, Structural modification techniques, Beams

The eigenvalue and eigenvector of a structure will change when damage is inflicted on the structure. The change should be related to the location and the extent of damage. The eigen-parameter, defined as the difference between the damaged and the undamaged case of the vector obtained by dividing the mass orthonormalized eigenvector by the corresponding eigenvalue, can be used as a means of locating the damage and as a measure of its significance.

86-2604

Computer Aided Fault Diagnosis in Turbo-Compressors Using Vibration Measurements

A. El Khatib, A. El Sayed

Alexandria Univ., Alexandria, Egypt

Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1403-1409, 8 figs, 7 tables, 10 refs

KEY WORDS: Experimental modal analysis, Diagnostic techniques, Turbomachinery, Rotatory compressors, Computer aided techniques

The main objective of this paper is to introduce a comprehensive diagnostic computer system based on recording and analyzing vibration spectra of running turbo-compressors to indicate their incipient failure. The proposed diagnostic system automatically warns of faults, enables diagnosis of the cause, and trends the historical data to predict ultimate breakdowns.

BALANCING

86-2605

Turbomachinery Incipient Failure Dynamic Detection Indicators and Analysis

D.R. Faby, R.L. Smith, J.L. Fratey

Shaker Res. Corp., Latham, NY

Rept. No. NASA-CR-178739, 54 pp (Aug 1985)
N86-21857/5/GAR

KEY WORDS: Diagnostic techniques, Failure detection, Ball bearings, Balls

Tape recorded signals from case-mounted accelerometers are examined to determine the feasibility of detecting spalls on bearing balls in the liquid oxygen pump in the space shuttle main engine. The nonperiodic nature of the spall impact on inner and outer bearing races caused traditional techniques to be unsuccessful. A

technique involving statistical techniques and spectra ratios was used to review available pump test tapes.

MONITORING

86-2606

Modal Frequency Method in Diagnosis of Fracture Damage in Structures

F.D. Ju, M. Mimovich

Univ. of New Mexico, Albuquerque, NM
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1168-1174, 10 figs, 4 tables, 8 refs

KEY WORDS: Diagnostic techniques, Beams, Fracture properties, Damage detection

The present paper used the modal frequency method to diagnose the fracture damage experimentally in simple structures, based on the analytic theory of the spring-loaded fracture-hinge. It is illustrated that the damage geometry uniquely defines the spring constant of the fracture hinge, which is therefore independent of the damage location. The experiment also measures the changes in modal frequencies to locate the damage on the beam. The locations of the damages can be predicted to within an accuracy of three percent of the length.

86-2607

The Calculation of Modal Balance Weights for Rotating Machinery

W.C. Foiles

Bently Nevada Corp., Broomall, PA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1518-1522, 6 refs

KEY WORDS: Experimental modal analysis, Balancing techniques, Rotating machinery

The relation between conventional balance weights and distributed balance weights is examined, with some discussion on equivalent sets of balance weights given. A mini-max algorithm is presented to calculate approximate modal forcing functions; in particular, modal balance weights. This algorithm is described as a linear programming problem.

86-2608

Application of Modal Analysis to the Balancing of Rotating Machines

R. Bigret

Institut Supérieur des Matériaux et de la Construction Mécanique, France
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1523-1530, 3 figs, 4 refs

KEY WORDS: Experimental modal analysis, Balancing techniques, Rotating machinery, Modal balancing technique, Influence coefficient method

A rotating machine includes a rotor, links and a structure. Its vibratory behavior is characterized by eigenvalues and by right and left eigenvectors which generally depend on the speed of rotation. The study of states with imposed forces enables to draw the principles of the modal method and the influence coefficient method for balancing. The relations between those two methods are expressed. The balancing, by means of two correcting unbalances, of a rotor which cannot be deformed and of a rotor in a rigid state is discussed.

86-2609

A Comparative Study of Vibration Monitoring Techniques for Rolling Element Bearings

M.A. Elbestawi, H.J. Tait

Ontario Hydro Research Division Toronto, Ontario, Canada
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1510-1517, 8 figs, 19 refs

KEY WORDS: Experimental modal analysis, Monitoring techniques, Rolling contact bearings, Vibration signatures, Signature analysis

Various vibration signature analysis techniques involving time, frequency and statistical methods are available for defect detection in rolling element bearings. This paper presents the results of an experimental investigation utilizing a bearing rig, evaluating the performance of some of these techniques in defect detection. Various defects were artificially induced in the tested bearings, and the resulting vibrations monitored using a piezoelectric accelerometer mounted on the bearing housing. A minicomputer system, interfaced with the test rig, was used to process the vibration signal. The paper presents data obtained at low and medium speeds and discusses the results.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

86-2610

Comments on Curve Veering in Eigenvalue Problems

N.C. Perkins, C.D. Mote, Jr.

Univ. of California, Berkeley, CA

J. Sound Vib., 106 (3), pp 451-463 (May 8, 1986)

12 figs, 1 table, 16 refs

KEY WORDS: Eigenvalue problems

The dependence of eigenvalues on a system parameter is frequently illustrated by a family of loci. When two loci approach each other, they often cross or abruptly diverge. The latter case, called curve veering, has been observed in approximate solutions associated with discretized models. The influence of discretization in producing curve veering has raised doubt on the validity of many approximate solutions. The existence of curve veering in continuous models is illustrated by presenting the exact solution of an elementary eigenvalue problem. Veering is then examined in a general eigenvalue problem. Criteria are established to distinguish veerings from crossings in both continuous and discretized models. The application of the criteria is illustrated by examples.

86-2611

The Reflection Function $r(t)$: A Matrix Approach Versus FFT^{-1}

J. Agullo, A. Barjau

Universitat Politecnica de Catalunya, Barcelona, Spain

J. Sound Vib., 106 (2), pp 192-201 (Apr 22, 1986) 8 figs, 1 table, 2 refs

KEY WORDS: Matrix methods, Fast fourier transform

The equation of a linear unidimensional acoustic system, expressed by means of the convolution integral relating pressure and velocity can be transformed into an equivalent equation. The equation is more convenient than the original equation because $r(t)$ decays to zero faster than $h(t)$. If the FFT^{-1} algorithm is used to obtain $r(t)$ a large number N' of points is required in order that the time interval be small; if the frequency interval is not to be too large. A matrix method is presented that allows one to compute $r(t)$ for any value of t , and which, to

obtain an array of points $r(t)$, compares favorably with FFT^{-1} . This method can be faster than FFT^{-1} if only a small number of modes are to be considered. If the damping is small modal coupling can be neglected, which leads to an approximate solution that greatly reduces the required computer capacity and time.

NUMERICAL METHODS

86-2612

A Numerical Technique for Nonlinear Eigenvalue Equations with Complex Roots and Its Application to Fluidelastic Vibration

T.T. Wu

Westinghouse Electric Corp., Pittsburgh, PA
Intl. Modal Analysis Conf., Proc. of the 4th, Los Angeles, CA, Feb 3-6, 1986, Vol. 2, pp 1577-1581, 3 figs, 7 refs

KEY WORDS: Fluid-structure interaction, Eigenvalue problems, Numerical methods

A sophisticated analytical model for fluidelastic vibration introduces the equations of fluid motion in addition to customary equations for structural motion. This results in a set of nonlinear eigenvalue equations with complex roots. The standard methods for eigenvalue and eigenvector extraction are not applicable mainly because of nonproportional damping and the dependency of the dynamic characteristics of the fluid-structure system on the flow velocity. This paper presents a numerical technique for solving nonlinear eigenvalue equations with complex roots.

PARAMETER IDENTIFICATION

86-2613

Parameter Estimation and Error Analysis in Environmental Modeling and Computations

E.E. Kalmaz

Johnson Space Center, Houston, TX

"Environmental Tech--Coming of Age", Proc. 32nd Ann. Tech. Mtg., Inst. of Env. Sci., Dallas/Ft. Worth, TX, May 6-8, 1986, pp 40-45, 2 figs, 12 refs

KEY WORDS: Parameter identification technique, Error analysis, Least squares method

One most important application of parameter estimation of system dynamics and the model development for environmental impact assessments is the provision of reliable estimates of parameters which can be used by means of sta-

tistical analysis. In most environmental modeling, parameter estimations and computational problems in pollutant clearance, elimination, half-life peaktme and concentration estimate can be obtained by curve fitting or structural modeling. This paper presents a method for the estimation of parameters and error analysis of the development of nonlinear modeling for environmental impact assessments studies. Modeling and least squares estimation techniques are used to define a model for association of error with experimentally observed data.

COMPUTER PROGRAMS

86-2614

EURDYN-1D: A Computer Code for the One-Dimensional Non-Linear Dynamic Analysis of Structural Systems. Description and Users' Manual (Release 1)

F. Casadei, J.P. Halleux

Commission of the European Communities,
Luxembourg

Rept. No. EUR-10115-EN, 198 pp (1985) PB86-189487/GAR

KEY WORDS: Computer programs, Dynamic structural analysis

The goal of the present report is to provide for a comprehensive users' manual describing the capabilities of the computer code EURDYN-1D. It includes information and examples about the

type of problems which can be solved with the code and explanation on how to prepare input data and, how to interpret output results. The field of application of EURDYN-1D is the one-dimensional dynamic analysis of general structural systems. The code is particularly suited for fast transient events involving propagation of longitudinal mechanical waves (subsonic) in structures.

GENERAL TOPICS

USEFUL APPLICATIONS

86-2615

Vibrating-Chamber Levitation Systems

M.B. Barmatz, D. Granett, M.C. Lee

NASA Pasadena Office, Pasadena, CA

U.S. Patent - 4 549 435, 6 pp (Oct 1985)

KEY WORDS: Levitation, Vibratory techniques

Systems are described for the acoustic levitation of objects, which enable the use of a sealed rigid chamber to avoid contamination of the levitated object. The apparatus includes a housing forming a substantially closed chamber, and means for vibrating the entire housing at a frequency that produces an acoustic standing wave pattern within the chamber.

PERIODICALS SCANNED

ACTA MECHANICA

(Acta Mech.)

Springer-Verlag New York, Inc.
175 Fifth Ave.
New York, NY 10010

ACTA MECANICA SOLIDE SINICA

(Acta Mech. Solida Sinica Chinese
Soc. Theo. Appl. Mech.)
Chinese Society of Theoretical
and Applied Mechanics
Guoji Shudian
P.O. Box 2820
Beijing, China

ACUSTICA

(Acustica)

S. Hirzel Verlag, Postfach 347
7000 Stuttgart 1
Fed. Rep. Germany

AERONAUTICAL JOURNAL

(Aeronaut. J.)

Royal Aeronautical Society
4 Hamilton Pl.
London W1V 0BQ, UK

AEROSPACE AMERICA

(Aerospace Amer.)

American Institute of Aeronautics
and Astronautics
1633 Broadway
New York, NY 10019

AEROSPACE ENGINEERING

(Aerospace Engrg.)

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

AIAA JOURNAL

(AIAA J.)

American Institute of Aeronautics
and Astronautics
1633 Broadway
New York, NY 10019

AMERICAN SOCIETY OF CIVIL ENGINEERS,

PROCEEDINGS

(ASCE, Proc.)

ASCE
United Engineering Center
345 E. 47th St.
New York, NY 10017

JOURNAL OF ENGINEERING MECHANICS
(ASCE J. Engrg. Mech.)

JOURNAL OF STRUCTURAL ENGINEERING
(ASCE J. Struc. Engrg.)

**AMERICAN SOCIETY OF LUBRICATION
ENGINEERS, TRANSACTIONS**

(ASLE, Trans.)

ASLE
838 Busse Highway
Park Ridge, IL 60068

**AMERICAN SOCIETY OF MECHANICAL ENGI-
NEERS, TRANSACTIONS**

(Trans. ASME)

ASME
United Engineering Center
345 E. 47th St.
New York, NY 10017

JOURNAL OF APPLIED MECHANICS
(J. Appl. Mech., Trans. ASME)

**JOURNAL OF DYNAMIC SYSTEMS, MEA-
SUREMENT AND CONTROL**
(J. Dynam. Syst., Meas. Control,
Trans. ASME)

**JOURNAL OF ENERGY RESOURCES TECH-
NOLOGY**
(J. Energy Resources Tech., Trans.
ASME)

JOURNAL OF ENGINEERING FOR INDUSTRY
(J. Engrg. Indus., Trans. ASME)

**JOURNAL OF ENGINEERING FOR GAS
TURBINES AND POWER**
(J. Engrg. Gas Turbines Power,
Trans. ASME)

**JOURNAL OF MECHANISMS, TRANSMISSION
AND AUTOMATION IN DESIGN**
(J. Mech., Transm., Autom. in Des.
Trans. ASME)

JOURNAL OF PRESSURE VESSEL TECHNOLOGY
(J. Pressure Vessel Tech., Trans.
ASME)

JOURNAL OF TURBOMACHINERY
(J. Turbomachinery, Trans. ASME)

JOURNAL OF TRIBOLOGY
(J. Trib., Trans. ASME)

**JOURNAL OF VIBRATION, ACOUSTICS,
STRESS, AND RELIABILITY IN DESIGN**
(J. Vib., Acoust., Stress, Rel.
Des., Trans. ASME)

APPLIED ACOUSTICS
(Appl. Acoust.)
Elsevier Applied Science
Publishers, Ltd.
Crown House, Linton Road
Barking, Essex, IG11 8JU, UK

ASTRONAUTICS AND AERONAUTICS
(Astronautics and Aeronautics)
1633 Broadway
New York, NY 10019

AUTOMOBILTECHNISCHE ZEITSCHRIFT
(Automobiltech. Z.)
Franckh'sche Verlagshandlung
W. Keller & Co., Postfach 640
Pfizerstrasse 5-7
D-700 Stuttgart 1
Fed. Rep. Germany

AUTOMOTIVE ENGINEER (UK)
(Auto. Engr. (UK))
Mechanical Engineering Publications
Ltd.
P.O. Box 24
Northgate Ave., Bury St. Edmunds
Suffolk IP32 6BW, UK

AUTOMOTIVE ENGINEERING (SAE)
(Auto. Engrg. (SAE))
Society of Automotive Engineers,
Inc.
400 Commonwealth Dr.
Warrendale, PA 15096

BALL BEARING JOURNAL (English Edition)
(Ball Bearing J.)
SKF (UK) Ltd.
Luton, Bedfordshire
LU3 3BL, UK

BROWN BOVERI REVIEW
(Brown Boveri Rev.)
Brown Boveri and Co., Ltd.
CH-5401, Baden, Switzerland

BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS
(Bull. JSME)
Japan Society of Mechanical Engineers
Sanshin Hokusei Bldg.,
H-9, Yoyogi 2-chome, Shibuya-ku
Tokyo, 151, Japan

BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA
(Bull. Seismol. Soc. America)
P.O. Box 826
Berkeley, CA 94705

CHARTERED MECHANICAL ENGINEER
(Chart. Mech. Engr.)
Institution of Mechanical Engineers
P.O. Box 24
Northgate Ave., Bury St. Edmunds
Suffolk IP32 6BW, UK

CHINA SCIENCE AND TECHNOLOGY ABSTRACTS
(China Sci. Tech. Abstracts)
International Information Service
Ltd.
P.O. Box 24683
ABD Post Office, Hong Kong

COMPRESSED AIR
(Compressed Air)
253 E. Washington Ave.
Washington, NJ 07882-2495

COMPUTERS AND STRUCTURES
(Computers Struc.)
Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

COMPUTERS IN MECHANICAL ENGINEERING**(Computers Mech. Engrg.)**

Springer-Verlag New York, Inc.
175 Fifth Ave.
New York, NY 10010

EXPERIMENTAL TECHNIQUES**(Exptl. Tech.)**

Society for Experimental Mechanics
Experimental Techniques
7 School Street
Bethel, CT 06801

DESIGN NEWS**(Des. News)**

Cahners Publishing Co., Inc.
221 Columbus Ave.
Boston, MA 02116

FEINGERATETECHNIK**(Feingeratetechnik)**

VEB Verlag Technik
Berlin,
German Dem. Rep.

DIESEL PROGRESS**(Diesel Prog.)**

Diesel and Gas Turbine Publications
13555 Bishop's Ct.
Brookfield, WI 53005-6286

FEINWERKTECHNIK UND MESSTECHNIK**(Feinwerktech. u. Messtech.)**

Carl Hanser Verlag
Kolbergerstr. 22
D-8000 Munchen 80
Fed. Rep. Germany

EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS**(Earthquake Engrg. Struc. Dynam.)**

John Wiley and Sons Ltd.
Baffins Lane
Chichester, Sussex PO19 1UD, England

FINITE ELEMENTS IN ANALYSIS AND DESIGN**(Finite Elements Analysis Des.)**

Elsevier Science Publishers
(North Holland)
P.O. Box 1991
1000 BZ Amsterdam
The Netherlands

ELECTRONIC PRODUCTS**(Electronic Prod.)**

Hearst Business Communications,
Inc.
P.O. Box 730
Garden City, NY 11530

FORSCHUNG IM INGENIEURWESEN**(Forsch. Ingenieurwesen)**

Verein Deutscher Ingenieur, GmbH
Postfach 1139, Graf-Recke Str. 84
4 Dusseldorf 1,
Fed. Rep. Germany

ENGINEERING STRUCTURES**(Engrg. Struc.)**

Butterworth Scientific, Ltd.
P.O. Box 63
Westbury House, Bury Street
Guildford, Surrey GU2 5BH, UK

GEC JOURNAL OF RESEARCH**(GEC J. Res.)**

Marconi Res. Ctr.
West Henningfield Rd.
Great Baddow, Chelmsford
Essex CM2 8HN, UK

ENGINEERING WITH COMPUTERS**(Engrg. Computers)**

Springer-Verlag New York, Inc.
175 Fifth Avenue
New York, NY 10010

GUMMI FASERN KUNSTSTOFFE**(Gummi Fasern Kunstst.)**

Alfons W. Gentner Verlag GmbH and Co. KG
ForstraBe 131, Postfach 688
7000 Stuttgart 1
Fed. Rep. Germany

EXPERIMENTAL MECHANICS**(Exptl. Mech.)**

Society for Experimental Mechanics
Experimental Mechanics
7 School Street
Bethel, CT 06801

HEATING/PIPING/AIR CONDITIONING**(Heating/Piping/Air Cond.)**

1111 Chester Avenue
Cleveland, OH 44114

**HIGH TECHNOLOGY
(High Tech.)**

High Technology Pub. Corp.
1642 Westwood Blvd.
Los Angeles, CA 90024

**HYDRAULICS AND PNEUMATICS
(Hydraul. Pneumat.)**

Penton/IPC, Inc.
614 Superior Ave. West
Cleveland, OH 44113

**HYDROCARBON PROCESSING
(Hydrocarbon Processing)**

Gulf Publishing Co.
P.O. Box 2608
Houston, TX 77001

IBM JOURNAL OF RESEARCH AND DEVELOPMENT

(IBM J. Res. Dev.)
International Business Machines
Corp.
Armonk, NY 10504

**INDUSTRIAL LUBRICATION AND TRIBOLOGY
(Indus. Lubric. Trib.)**

Peterson Publishing Co. Ltd.
Peterson House, Northbank,
Berryhill Industrial Estate
Droitwich, Worcs WR9 9BL, England

**INDUSTRIE-ANZEIGER
(Industrie-Anz.)**

Verlag W. Girardet, Girardetstr. 2
Postfach 101365
4300 Essen, W. Germany

**INGENIEUR-ARCHIV
(Ing.-Arch.)**

Springer-Verlag New York, Inc.
44 Hartz Way
Secaucus, NJ 07094

**INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, PROCEEDINGS
(IEEE, Proc.)**

IEEE
United Engineering Center
345 E. 47th St.
New York, NY 10017

**INSTITUTION OF MECHANICAL ENGINEERS,
PROCEEDINGS, PART C: MECHANICAL
ENGINEERING SCIENCE
(IMechE, Proc. Part C: Mech. Engrg.
Sci.)**

Institution of Mechanical Engineers
1 Birdcage Walk, Westminster,
London SW1H 9JJ, UK

INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS

(ISA, Trans)
Instrument Society of America
67 Alexander Dr.
Research Triangle Park, NC 27709

**INSTRUMENTATION TECHNOLOGY
(Instrum. Tech.)**

Instrument Society of America
67 Alexander Dr.
P.O. Box 12277
Research Triangle Park, NC 27709

**INTERNATIONAL JOURNAL OF ANALYTICAL
AND EXPERIMENTAL MODAL ANALYSIS
(Intl. J. Analyt. Exptl. Modal
Analysis)**

Society for Experimental Mechanics,
Inc.
7 School Street
Bethel, CT 06801

**INTERNATIONAL JOURNAL OF ENGINEERING
SCIENCE**

(Intl. J. Engrg. Sci.)
Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

**INTERNATIONAL JOURNAL OF FATIGUE
(Intl. J. Fatigue)**

Butterworth Scientific Ltd.
Journals Div.
P.O. Box 63, Westbury House, Bury
St.
Guildford GU2 5BH, Surrey, UK

**INTERNATIONAL JOURNAL OF IMPACT
ENGINEERING**

(Intl. J. Impact Engrg.)
Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

**INTERNATIONAL JOURNAL OF MACHINE TOOL
DESIGN AND RESEARCH**

(Intl. J. Mach. Tool Des. Res.)
Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

**INTERNATIONAL JOURNAL OF MECHANICAL
SCIENCES**

(Intl. J. Mech. Sci.)
Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS

(*Intl. J. Nonlin. Mech.*)

Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS

(*Intl. J. Numer. Anal. Methods Geo-mech.*)

John Wiley and Sons Ltd.
Baffins Lane
Chichester, Sussex PO19 1UD, England

INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING

(*Intl. J. Numer. Methods Engrg.*)

John Wiley and Sons Ltd.
Baffins Lane
Chichester, Sussex PO19 1UD, England

INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES

(*Intl. J. Solids Struc.*)

Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

INTERNATIONAL JOURNAL OF VEHICLE DESIGN

(*Intl. J. Vehicle Des.*)

Interscience Enterprises Ltd.
World Trade Center Building
110 Avenue Louis Casai,
Case Postale 306
CH1215 Geneva-Aeroport,
Switzerland

ISRAEL JOURNAL OF TECHNOLOGY

(*Israel J. Tech.*)

Weizmann Science Press of Israel
Box 801
Jerusalem, Israel

JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA

(*J. Acoust. Soc. Amer.*)

American Institute of Physics
335 E. 45th St.
New York, NY 10017

JOURNAL OF AIRCRAFT
(*J. Aircraft*)

American Institute of Aeronautics
and Astronautics
1633 Broadway
New York, NY 10019

JOURNAL OF COMPOSITES AND TECHNOLOGY RESEARCH

(*J. Comp. Tech. Res.*)

ASTM-CTR
1916 Race Street
Philadelphia, PA 19103

JOURNAL OF ENVIRONMENTAL SCIENCES

(*J. Environ. Sci.*)

Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

JOURNAL OF THE FRANKLIN INSTITUTE
(*J. Franklin Inst.*)

Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

JOURNAL OF LOW FREQUENCY NOISE AND VIBRATION

(*J. Low Freq. Noise Vib.*)

Multi-Science Publishing Co.,
107 High Street
Brentwood, Essex CM14 4RX
England

JOURNAL DE MÉCANIQUE THÉORIQUE ET APPLIQUÉE

(*J. de Mécanique Théor. Appl.*)

Gauthier-Villars
C.D.R. - Centrale des Régues
11, rue Gossin, 92543 Montrouge,
Cedex, France

JOURNAL OF PETROLEUM TECHNOLOGY

(*J. Pet. Tech.*)

Society of Petroleum Engineers
222 Palasades Creek Drive
Richardson, TX 75080

JOURNAL OF SHIP RESEARCH

(*J. Ship Res.*)

Society of Naval Architects and
Marine Engineers
One World Trade Center
Suite 1369
New York, NY 10048

JOURNAL OF SOUND AND VIBRATION**(J. Sound Vib.)**

Academic Press Inc. (London)
 Limited
 Oval Road
 London NW1 7DX UK

JOURNAL OF SPACECRAFT AND ROCKETS**(J. Spacec. aft. Rockets)**

American Institute of Aeronautics
 & Astronautics
 1623 Broadway
 New York, NY 10019

JOURNAL OF STRUCTURAL MECHANICS**(J. Struc. Mech.)**

Marcel Dekker, Inc.
 270 Madison Ave.
 New York, NY 10016

KONSTRUKTION**(Konstruktion)**

Springer-Verlag
 Heidelberger Platz 3, D-1000
 Berlin 33
 Fed. Rep. Germany

LUBRICATION ENGINEERING**(Lubric. Engrg.)**

American Society of Lubrication
 Engineers
 838 Busse Highway
 Park Ridge, IL 60068

MACHINE DESIGN**(Mach. Des.)**

Penton/IPC, Inc.
 Penton Plaza,
 1111 Chester Ave.
 Cleveland, OH 44114

MASCHINENBAUTECHNIK**(Maschinenbautech.)**

VEB Verlag Technik
 Oranienburger Str. 13/14
 1020 Berlin,
 German Dem. Rep.

MECCANICA**(Meccanica)**

Pitigora Editrice
 Via Zamboni 57
 Bologna, Italy
 C.C.P. 17396409

MECHANICAL ENGINEERING**(Mech. Engrg.)**

American Society of Mechanical
 Engineers
 United Engineering Center
 345 E. 47th St.
 New York, NY 10017

MECHANICS RESEARCH COMMUNICATIONS**(Mech. Res. Comm.)**

Pergamon Press Inc.
 Maxwell House, Fairview Park
 Elmsford, NY 10523

MECHANISM AND MACHINE THEORY**(Mech. Mach. Theory)**

Pergamon Press Inc.
 Maxwell House, Fairview Park
 Elmsford, NY 10523

MICROTECNIC**(Microtechnic)**

Agifa Verlag
 Universitatstrasse 94
 P O. Box 257
 CH-8033 Zurich, Switzerland

MTZ MOTORTECHNISCHE ZEITSCHRIFT**(MTZ Motortech. Z.)**

Franckh'sche Verlagshandlung
 Pfizerstrasse 5-7
 D-7000 Stuttgart 1,
 Fed. Rep. Germany

NAVAL ENGINEERS JOURNAL**(Naval Engr. J.)**

American Society of Naval Engi-
 neers, Inc.
 1452 Duke Street
 Alexandria, VA 22314

NONDESTRUCTIVE TESTING INTERNATIONAL**(NDT Intl.)**

Butterworth Scientific Ltd.
 Journals Div.
 P.O. Box 63, Westbury House, Bury
 St.
 Guildford, Surrey GU2 5BH, UK

NOISE CONTROL ENGINEERING JOURNAL**(Noise Control Engrg. J.)**

P.O. Box 2306, Arlington Branch
 Poughkeepsie, NY 12603

NOISE & VIBRATION CONTROL

(**Noise & Vib. Control**)

The Trade & Technical Press Ltd.
Crown House
Morden
Surrey, SM4 5EW, England

NUCLEAR ENGINEERING AND DESIGN

(**Nucl. Engrg. Des.**)

North-Holland Publishing Co.
P.O. Box 1000 AC
Amsterdam, The Netherlands

OCEAN ENGINEERING

(**Ocean Engrg.**)

Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, NY 10523

PAPER TECHNOLOGY AND INDUSTRY

(**Paper Tech. Indus.**)

3, Plough Place, Fetter Lane
London EC4A 1AL, UK

PHYSICS TODAY

(**Physics Today**)

American Institute of Physics
500 Sunnyside Blvd.
Woodbury, NY 11797

PLANT ENGINEERING

(**Plant Engrg.**)

Technical Publishing Co.
1301 S. Grove Ave.
Barrington, IL 60010

POWER

(**Power**)

McGraw-Hill, Inc.
1221 Ave. of Americas
New York, NY 10020

POWER TRANSMISSION DESIGN

(**Power Transm. Des.**)

Penton IPC/Inc.
1111 Chester Ave.
Cleveland, OH 44114

REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MECANIQUE APPLIQUEE
(**Rev. Roumaine Sci. Tech., Mecanique Appl.**)

Editura Academiei
Republicii Socialiste de Romania
125, Calea Victoriei, 79717
Bucarest, Romania

SAE TECHNICAL LITERATURE ABSTRACTS

(**SAE Tech. Lit. Abstracts**)

Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15086

SCIENTIFIC AMERICAN

(**Scientific American**)

Scientific American, Inc.
415 Madison Ave.
New York, NY 10017

SHOCK AND VIBRATION DIGEST

(**Shock Vib. Dig.**)

Shock and Vibration Information
Center
Naval Research Laboratory, Code
5804
Washington, DC 20375

SIAM JOURNAL ON APPLIED MATHEMATICS

(**SIAM J. Appl. Math.**)

Society for Industrial and Applied
Mathematics
1400 Architects Building
117 S. 17th St.
Philadelphia, PA 19103

SIEMENS RESEARCH AND DEVELOPMENT REPORTS

(**Siemens Res. Dev. Repts.**)

Springer-Verlag New York Inc.
175 Fifth Ave.
New York, NY 10010

STROJNICKÝ ČASOPIS

(**Strojnický Casopis**)

83606 Bratislava
ul. Febr. vitezstva 75
Czechoslovakia

S/V, SOUND AND VIBRATION

(**S/V, Sound Vib.**)

Acoustic Publications, Inc.
27101 E. Oviatt Rd.
P.O. Box 40416
Bay Village, OH 44140

TAPPI JOURNAL

(**Tappi J.**)

Technical Association of the Pulp
and Paper Industry
15 Technology Park South
Norcross, GA 30092

TECHNICAL REVIEW (BRUEL and KJAER)

(Tech. Rev. (B and K))

Brüel and Kjaer
185 Forest St.
Marlborough, MA 01752

TECHNISCHE MITTEILUNGEN KRUPP,

FORSCHUNGSBERICHTE

(Techn. Mitt. Krupp, Forschungsber.)

Krupp Gemeinschaftsbetriebe,
Fachbücherei,
Postfach 10 19 52, D-4300 Essen 1,
Fed. Rep. Germany

TECHNISCHE MITTEILUNGEN KRUPP,

WERKSBERICHTE

(Techn. Mitt. Krupp, Werksber.)

Krupp Gemeinschaftsbetriebe,
Fachbücherei,
Postfach 10 19 52, D-4300 Essen 1,
Fed. Rep. Germany

TECHNISCHES MESSEN-TM

(Techn. Messen-TM)

R. Oldenbourg Verlag GmbH
Rosenheimer Strasse 145,
D-8000 München 80,
Fed. Rep. Germany

TEST

(Test)

Mattingley Publishing Co., Inc.
3756 Grand Ave.
Suite 205
Oakland, CA 94610

TRIBOLOGY INTERNATIONAL

(Trib. Intl.)

Butterworth Scientific Ltd.
Journals Div.
P.O. Box 63,
Westbury House, Bury St.
Guildford, Surrey GU2 5BH, UK

TURBOMACHINERY INTERNATIONAL

(Turbomachinery Intl.)

270 Madison Ave.
New York, NY 10016

VDI BERICHTE

(VDI Ber.)

Verein Deutscher Ingenieur GmbH
Postfach 1139, Graf-Recke Str. 84,
4 Düsseldorf 1,
Fed. Rep. Germany

VDI FORSCHUNGSHAFT

(VDI Forsch.)

Verein Deutscher Ingenieur GmbH
Postfach 1139, Graf-Recke Str. 84,
4 Düsseldorf 1,
Fed. Rep. Germany

VDI ZEITSCHRIFT

(VDI Z.)

Verein Deutscher Ingenieur GmbH
Postfach 1139, Graf-Recke Str. 84,
4 Düsseldorf 1,
Fed. Rep. Germany

VERTICA

(Vertica)

Pergamon Press
Maxwell House, Fairview Park
Elmsford, NY 10523

VIBRATIONS

(Vibrations)

Vibration Institute
101 W. 55th Street
Suite 206
Clarendon Hills, IL 60514

VIBROTECHNIKA

(Vibrotechnika)

Kauno Polytechnikos Institutas
2 Donelaicio g-ve 17
23300 Kaunas,
Lithuanian SSR

WAVE MOTION

(Wave Motion)

Elsevier Science Publishers B.V.
Molenwerf 1, P.O. Box 1991
1000 BZ Amsterdam,
The Netherlands

WEAR

(Wear)

Elsevier-Sequoia S.A.
P.O. Box 851
1001 Lausanne 1,
Switzerland

ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN UND WELTRAUMFORSCHUNG

(Z. Flugwiss. Weltraumforsch.)

DFVLR
D-3300 Braunschweig
Flughafen, Postfach 3267,
Fed. Rep. Germany

SECONDARY PUBLICATIONS SCANNED

**DISSERTATION ABSTRACTS INTERNATIONAL
(DA)**

University Microfilms International
300 N. Zeeb Rd.
Ann Arbor, MI 48106

**GOVERNMENT REPORTS ANNOUNCEMENTS AND
INDEX
(GRA)**

National Technical Information
Service
U.S. Department of Commerce
5285 Port Royal Rd.
Springfield, VA 22161

PROCEEDINGS SCANNED

**INTERNATIONAL MODAL ANALYSIS
CONFERENCE**

(Intl. Modal Anal. Conf.
Union College
Schenectady, NY 12308

**INTER-NOISE PROCEEDINGS, INTERNATIONAL
CONFERENCE ON NOISE CONTROL ENGINEERING**

(Inter-Noise)
Noise Control Foundation
P.O. Box 3469, Arlington Branch
Poughkeepsie, NY 12603

**INSTITUTE OF ENVIRONMENTAL SCIENCES
PROCEEDINGS**

(Inst. Environ. Sci.)
950 East Northwest Highway
Mount Prospect, IL 60056

**MACHINERY VIBRATION MONITORING AND
ANALYSIS MEETING, PROCEEDINGS**

(Mach. Vib. Monit. Anal., Proc.)
The Vibration Institute
101 W. 55th St., Suite 206
Clarendon Hills, IL 60514

**NOISE CONTROL PROCEEDINGS, NATIONAL
CONFERENCE ON NOISE CONTROL ENGINEER-
ING**

(Noise Control)
Noise Control Foundation
P.O. Box 3469, Arlington Branch
Poughkeepsie, NY 12603

**THE SHOCK AND VIBRATION BULLETIN,
UNITED STATES NAVAL RESEARCH LABORA-
TORIES, ANNUAL PROCEEDINGS**

**(Shock Vib. Bull., U.S. Naval Res.
Lab., Proc.)**
Shock and Vibration Information
Center
Naval Research Lab., Code 5804
Washington, DC 20375

TURBOMACHINERY SYMPOSIUM

(Turbomachinery Symp.)
Gas Turbine Labs.
Texas A and M University
College Station, TX 77843

ABSTRACT CATEGORIES

MECHANICAL SYSTEMS

Rotating Machines
Reciprocating Machines
Power Transmission Systems
Metal Working and Forming
Isolation and Absorption
Electromechanical Systems
Optical Systems
Materials Handling Equipment

Blades
Bearings
Belts
Gears
Clutches
Couplings
Fasteners
Linkages
Valves
Seals
Cams

Vibration Excitation
Thermal Excitation

STRUCTURAL SYSTEMS

Bridges
Buildings
Towers
Foundations
Underground Structures
Harbors and Dams
Roads and Tracks
Construction Equipment
Pressure Vessels
Power Plants
Off-shore Structures

STRUCTURAL COMPONENTS

Strings and Ropes
Cables
Bars and Rods
Beams
Cylinders
Columns
Frames and Arches
Membranes, Films, and Webs
Panels
Plates
Shells
Rings
Pipes and Tubes
Ducts
Building Components

EXPERIMENTATION

Measurement and Analysis
Dynamic Tests
Scaling and Modeling
Diagnostics
Balancing
Monitoring

VEHICLE SYSTEMS

Ground Vehicles
Ships
Aircraft
Missiles and Spacecraft

ELECTRIC COMPONENTS

Controls (Switches,
Circuit Breakers)
Motors
Generators
Transformers
Relays
Electronic Components

ANALYSIS AND DESIGN

Analogs and Analog
Computation
Analytical Methods
Modeling Techniques
Nonlinear Analysis
Numerical Methods
Statistical Methods
Parameter Identification
Mobility/Impedance Methods
Optimization Techniques
Design Techniques
Computer Programs

BIOLOGICAL SYSTEMS

Human
Animal

MECHANICAL COMPONENTS

Absorbers and Isolators
Springs
Tires and Wheels

DYNAMIC ENVIRONMENT

Acoustic Excitation
Shock Excitation

GENERAL TOPICS

Conference Proceedings
Tutorials and Reviews
Criteria, Standards, and
Specifications
Bibliographies
Useful Applications

FEATURE ARTICLES

	ISSUE	PAGES
Casceiro, C.A. Behavior of Elastomeric Materials under Dynamics Load — IV	1	3-6
Stadelbauer, D.G. Dynamic Balancing with Micro Processors	2	3-6
Laura, P.A.A. The Computer Age And The Usefulness of Old Ideas	3	3-5
Spanos, P.D. and Lutes, L.D. A Primer of Random Vibration Techniques in Structural Engineering	4	3-9
Gupta, A.K. Finite Element Analysis of Vibration of Tapered Beams	5	3-6
Mukherjee, A. and Mukhopadhyay, M. A Review of Dynamic Behavior of Stiffened Plates	6	3-8
Greif, R. Substructuring and Component Mode Synthesis	7	3-9
Rades, M. System Identification Using Real Frequency-Dependent Modal Characteristics	8	3-10
deSilva, C.W., Henning, S.J., and Brown, J.D. Random Testing with Digital Control — Application in the Distribution Qualification of Microcomputers	9	3-13
deSilva, C.W. The Digital Processing of Acceleration Measurements for Modal Analysis	10	3-10
Silva, M.A.G. and Krajcinovic, D. Impact Strength of Concrete	11	3-6
Hundal, M.S. Mechanical Signature Analysis	12	3-10

LITERATURE REVIEWS

	ISSUE	PAGES
France, D. Rotor Instability in Centrifugal Pumps	1	9-13
Sankar, T.S. and Samaha, M. Research in Rail Vehicle Dynamics — State of the Art	2	9-18
Rao, S.S. Optimization of Structures Under Shock and Vibration Environment	3	7-15
Al-Mousawi, M.M. Theoretical Studies on Flexural Wave Propagation in Beams: A Comprehensive Review — Part I: Historical Background	4	11-18
Al-Mousawi, M.M. Theoretical Studies on Flexural Wave Propagation in Beams: A Comprehensive Review — Part II: Transient Response of Timoshenko Beams	5	9-21
Al-Mousawi, M.M. Theoretical Studies on Flexural Wave Propagation in Beams: A Comprehensive Review — Part III: Wave Propagation in Beams with Discontinuities of Cross Section	6	11-18
Beltzer, A.I. Wave Propagation in Random Composite Materials	7	11-15
Done, G.T.S. Helicopter Vibration Control — Recent Advances	8	13-17
Adeli, H., Amin, A.M., and Sierkowski, R.L. Earth Penetration by Solid Impactors	9	15-22
Nicholson, D.W. Stable Response of Damped Linear Systems — III	10	13-19
Trainor, P.G.S., Popplewell, N., Shah, A.H., and Wong, C.K. Static and Dynamic Behavior of Mechanical Components Associated with Electrical Transmission Lines — II	11	9-17
Broek, D. Fracture Analysis — A Review	12	13-22

BOOK REVIEWS

Brebbia, C.A., Telles, J.C.F., Wrobel, L.C., Boundary Element Techniques, Springer-Verlag, New York and Berlin, 1984; Reviewed by H. Saunders, SVD, 18 (9), pp 23-24 (Sept 1986).

Bulson, P.S., Buried Structures. Static and Dynamic Strength, Chapman and Hall/Methuen, Inc., New York, NY, 1985; Reviewed by S.A. Kiger, SVD, 18 (4), p 20 (Apr 1986).

Chandra, J. and Scott, A.C., Coupled Nonlinear Oscillator, North-Holland Publishing Company, Amsterdam, 1983; Reviewed by R.A. Ibrahim, SVD, 18 (7), pp 17-18 (July 1986).

Chen, P.Y. and Grimes, C.J., Eds., Seismic Events Probabilistic Risk Assessments, American Society of Mechanical Engineers, New York, NY, 1984; Reviewed by H. Saunders, SVD, 18 (8), p 18 (Aug 1986).

Cheremisinoff P.N. and Ellerbusch, F., Guide for Industrial Noise Control, Butterworth Publishers, Ann Arbor Science, Ann Arbor, MI, 1982; Reviewed by R.J. Peppin, SVD, 18 (8), pp 18-19 (Aug 1986).

Crocker, T.W. and Leis, B.N., eds., Corrosion Fatigue, ASTM Pub STP 801, ASTM, Philadelphia, Pa, 1985; Reviewed by H. Saunders, SVD, 18 (4), pp 21-20 (Apr 1986).

Datta, S.K., ed., Earthquake Source Modelling, Ground Motion and Structural Response, ASME Pub., 1984; Reviewed by H. Saunders, SVD, 18 (9), pp 24-25 (Sept 1986).

Dowding, C.H., Blast Vibration Monitoring and Control, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1985; Reviewed by W.E. Baker, SVD, 18 (1), p 14 (Jan 1986).

D'Souza, A.F. and Garg, V.K., Advanced Dynamics -- Modelling and Analysis, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1984; Reviewed by H. Saunders, SVD, 18 (7), pp 16-17 (July 1986).

Englekirk, R.E., Hart, G.C., and Concrete Masonry Assoc. of California and Nevada, Prentice Hall, Inc., Englewood Cliffs, NY, 1982; Reviewed by S.E. Benzley, SVD, 18 (12), p 24 (Dec 1986).

Fahy, F., Sound and Structural Vibration: Radiation, Transmission and Response, Academic Press, London, 1985; Reviewed by R.J. Peppin, SVD 18 (11), pp 18-19 (Nov 1986).

Gough, W., Richards, J.P.G., and Williams, R.P., Vibrations and Waves, Halsted Press, New York, NY, 1983; Reviewed by R.A. Scott, SVD, 18 (10), p 22 (Oct 1986).

Guckenheimer, J. and Holmes, P., Review of Nonlinear Oscillations. Dynamical Systems, And Bifurcations of Vector Fields, Springer Verlag, New York, New York, NY, 1983; Reviewed by R.A. Scott, SVD, 18 (5), p 22 (May 1986).

Ibrahim R.A., Parametric Random Vibration, John Wiley & Sons, Inc., New York, NY, 1985; Reviewed by P.W. Whaley, SVD, 18 (10), pp 22-23 (Oct 1986).

Kabe, A.W., Organizer, Structural Dynamic Testing and Analysis, SAE, Warrendale, PA, 1984; Reviewed by H. Saunders, SVD, 18 (2), pp 20-21 (Feb 1986).

Kramer, E., Maschinendynamik, Springer Verlag, New York, NY, 1984; Reviewed by S.M. Holzer, SVD, 18 (5), pp 22-23 (May 1986).

Lalanne, M., Berthia, P., and der Hagopian, J., Mechanical Vibrations for Engineers, John Wiley & Sons, New York, NY, 1983; Reviewed by H. Saunders, SVD, 18 (1), pp 14-15 (Jan 1986).

Meirovitch, L., Introduction to Dynamics and Control, John Wiley & Sons, New York, NY, 1985; Reviewed by R.A. Ibrahim, SVD, 18 (2), pp 19-20 (Feb 1986).

Nashif, A.D., Jones, D.J.G., and Henderson, J.P., Vibration Damping, John Wiley & Sons, Inc., New York, NY, 1985; Reviewed by V.R. Miller, SVD, 18 (3), pp 16-17 (Mar 1986).

Nayfeh, Ali H., Problems in Perturbation, John Wiley & Sons, New York, NY, 1985; Reviewed by R.A. Ibrahim, SVD, 18 (12), pp 23-24 (Dec 1986).

Oppenheim, A.V., Willsky, A.S., and Young, I.F., Signals and Systems, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1983; Reviewed by H. Saunders, SVD, 18 (6), pp 19-20 (June 1986).

Rao, J.S. and Gupta, K., Introductory Course on Theory and Practice of Mechanical Vibrations, John Wiley & Sons Inc., New York, NY, 1984; Reviewed by W.D. Pilkey, SVD, 18 (3), p 16 (Mar 1986).

Sharpe, R.S., ed., Research Techniques in Nondestructive Testing -- Vol. VII, Academic Press, London, 1984; Reviewed by S.E. Benzley, SVD, 18 (11), p 18, (Nov 1986).

Varanauskas, P.A., Kurtinaitis, A.K., and Ragulskis, K.M., Methods and Means of Experimental Analysis of the Dynamics of Precise Tape Drives, Moksas Publ., Vilnius Lithuanian SSR, 1982; Reviewed by A. Longinow, SVD, 18 (3), pp 17-18 (Mar 1986).

Walshaw, A.C., Mechanical Vibrations With Applications, Ellis Horwood, Ltd., 1984; Reviewed by T.S. Sankar, SVD, 18 (4), pp 20-21 (Apr 1986).

White, R.G. and Walker, J.G. (editors), Noise and Vibration, Ellis Horwood (John Wiley) Chichester, 1982; Reviewed by R.J. Peppin, SVD, 18 (6), p 19 (June 1986).

AUTHOR INDEX

- A -

Abascal, R.....	1714	Akbar, H.....	1903
Abbas, B.A.H.....	2182	Akella, S.....	2380
Abdalla, M.H.M.....	2394	Akers, A.....	947
Abdelhamid, M.K.....	1812	Akers, S.....	2536
Abdel-Ghaffar, A.M.....	775, 951, 952	Akita, Tetsuyoshi.....	2376
Abdel-Hamid, A.N.....	1510	Akiyama, H.....	407
Abdel-Rahman, S.....	1890	Akkas, N.....	1980
Abdel-Rohman, M.....	609, 2216	Aknine, A.....	1624
Abdulhadi, M.I.....	59	Aksel, N.....	2294
Abd-Rabbo, A.....	2480	Aksu, G.....	1583, 1774
Abe, K.....	926, 1725	Aktan, A.E.....	661
Abe, T.....	1567	Aktan, H.M.....	1673
Abel, J.F.....	625	Alam, N.....	1429
Abel, S.G.....	257	Alanoly, J.....	2405
Abkowitz, M.A.....	308	Alarcon, L.F.....	1379
Abom, M.....	1614	Alavandi, B.V.....	1997
Aboustit, B.L.....	525	Albrecht, D.....	978, 1051
Abo-Elkhier, M.....	2241	Albrecht, P.....	545
Abramovich, H.....	592, 1607	Alexander, J.C.....	1842
Abrams, D.P.....	1709	Alexandropoulos, A.....	2210
Abt, S.R.....	456	Alfred, J.R.....	1410
Abu-Arish, A.M.....	1346	Ali, S.A.....	1039, 1599, 1756
Achenbach, J.D.....	93, 2202	Alibe, B.....	1722
Adachi, Tsutomu.....	1267	Allaire, P.E.....	1745
Adachi, T.....	2004	Allard, J.F.....	707, 1624
Adali, S.....	118	Allemand, R.J.....	904, 1690, 2209
Adams, M.L.....	593	Allen, B.G.....	2208
Adams, ..M.....	1076	Allen, J.J.....	486
Adamson, T.C., Jr.....	1801	Allison, I.M.....	61
Adeli, H.....	672	Altman, W.....	1999
Adeyeye, J.O.....	260	Alwan, A.D.....	2396
Adhami, R.....	1489	AL-Ansary, M.D.....	2337
Adin, M.A.....	833	Al-Mousawi, M.M.....	1760, 1973, 2203
Adler, L.....	1787	Al-Noury, S.I.....	1039, 1599
Aernoudt, E.....	1117	Al-Sabeeh, A.K.....	281
Aggarwal, A.K.....	2191	Al-Sulaimani, G.J.....	939
Agrawal, O.P.....	507, 1329	Amada, S.....	279, 2377
Agrwal, V.P.....	508	Amber, J.....	286
Agullo, J.....	2611	Amer, M.I.M.....	909
Ahlawalia, D.S.....	162	Amiet, R.K.....	2271
Ahmad, S.....	2350	Amberman, W.B.....	2449
Ahmadi, A.R.....	1558	Anand, G.V.....	2495
Ahmadi, G.....	1766, 1890, 2233	Anand, N.M.....	1201
Ahmadian, M.....	1680	Anand, S.C.....	150
Ahola, R.....	218	Ananthakrishnan, S.....	1132
Ahuja, K.K.....	567, 568, 569, 570	Ananthanarayana, N.....	702, 2437
Ahuja, S.....	501	Andersen, P.....	1422
Aimoto, T.....	446	Anderson, C.W.....	1038, 1440
Ajima, T.....	1954	Anderson, G.D.....	1089
Akay, A.....	2348	Anderson, G.L.....	821
		Anderson, G.S.....	1791
		Anderson, I.....	1729
		Anderson, M.J.....	1075, 1077

Anderson, M.S.....	1266, 1417, 1683	Baber, T.T.....	892, 1982
Ando, Tsuneyo.....	2014	Babott, F.....	2264
Andress, E.A.....	2576	Babu, C.R.....	2205
Andrews, G.B.....	2432	Baca, T.J.....	1831
Andrews, J.R.....	1484	Bachmann, H.....	1814
Ang, A.H.-S.....	549, 960, 961	Badawy, E.M.....	2378
Ansari, K.A.....	1575, 1578, 1931	Badrakhan, F.....	692
Anton, E.....	537	Baeder, J.D.....	1743
Antony, G.....	1569	Baetz, W.....	1736
Aoki, S.....	458	Baganoff, D.....	2259
Apostolescu, V.I.....	972	Bagley, R.L.....	471
Arakawa, T.....	145	Bahat, L.Y.....	886
Araki, Y.....	95, 473, 536, 2089	Baharlou, B.....	1430
Araha, J.A.P.....	2148	Bai, Jing.....	870
Arbey, H.....	1612	Baier, H.....	2167
Arendts, J.G.....	2242, 2243	Baik, Joo Hyun.....	300
Argyris, J.....	198	Bailey, T.....	1040
Ariaratnam, S.T.....	2238	Bainum, P.M.....	1132, 1233
Arndt, R.E.A.....	1456	Bai-ling, Zhou.....	1158
Arnold, J.M.....	1661	Bajkowski, J.....	1467
Arnold, L.....	2101	Baker, A.....	802
Arnold, P.....	770	Baker, M.....	2069
Arnold, R.R.....	509	Baker, W.E.....	1195
Arnold, W.....	985	Bakewell, H.....	872
Arpacı, A.....	2226	Balasubramaniam, R.....	2152
Artos, J.K.....	853	Baldwin, G.R.....	246
Artuso, J.W.....	2444	Baldwin, J.F.....	1127
Arya, A.S.....	1522	Balena, F.J.....	39
Arzoumanidis, S.G.....	1175	Balendra, T.....	112, 617, 1183, 1524
Asami, T.....	1653	Balfour, J.A.D.....	2136
Asfar, K.R.....	1966	Balmer, H.A.....	1908
Asfura, A.....	1794	Balon, K.....	1816
Ashraf Ali, M.....	1472	Bamberger, Y.....	14
Ashwill, T.D.....	1704	Banaszak, D.L.....	1338
Ashworth, D.A.....	1249	Banerjee, B.....	2000
Asnani, N.T.....	392, 1429	Banerjee, J.F.....	1264
Aspragathos, N.....	1749	Banerjee, J.R.....	827, 1045
Assadi, M.....	829	Banerjee, P.K.....	1385, 2350
Astaneh-Asl, A.....	603	Baniotopoulos, C.C.....	1577
Atadan, A.S.....	262	Banks, H.T.....	830
Atallah, G.C.....	1347	Banon, H.....	29
Atkin, R.J.....	436	Banu, H.....	649
Attenborough, K.....	434, 442	Bapat, C.N.....	1478
Aubert, A.C.....	1406	Barclay, D.W.....	145, 854
Austin, E.M.....	1105	Barietta, R.....	1238
Austin, M.A.....	842, 2110	Barjau, A.....	2611
Au-Yang, M.K.....	990, 2010	Barker, J.C.....	2585
Avanessian, V.....	1441, 1896	Barksy, M.....	427
Avitabile, P.....	2300, 2565	Barlow, J.....	140
Avram, J.....	976	Barmatz, M.B.....	2615
Axelrad, V.....	178, 1454	Baron, J.....	1433
Ayabe, Takashi.....	1539	Baroncelli, A.....	142
Ayabe, T.....	366	Barrett, L.E.....	1937, 2371
Azar, J.J.....	1173	Barta, D.A.....	1075
Azayem, K.M.....	2337	Barter, N.F.....	601
Azizinamini, A.....	370	Barthelet, B.....	987
Babcock, C.D.....	1195	Barthell, J.F.....	2575
		Baruh, H.....	936
		Bar-shalom, Y.....	1732
		Bassani, R.....	142

Basu, P.....	1935	Berry, J.E.....	2336
Basu, T.K.....	703	Bert, C.W.....	1445
Bates, S.....	2272	Bertero, V.V.....	661
Bathe, K.J.....	134	Bertram, A.L.....	1440
Batis, J.H.....	1770	Bertrand, B.P.....	875
Batra, N.K.....	1142	Beskos, D.E.....	1763
Batterson, J.G.....	2407	Bessler, W.....	215
Bauer, H.F.....	800	Betteridge, D.....	223
Baumeister, K.J.....	1626, 2030	Bettles, R.W.....	1409
Bavendiek, R.....	749	Beucke, K.E.....	685
Baxter, B.J.....	1971	Bevan, B.G.....	601
Baxter, L.....	157	Beyer, T.B.....	999
Baxter, N.L.....	1129	Bezler, P.....	1294
Beards, C.F.....	897, 1403	Bhaskar, K.....	1285
Beattie, K.R.....	337	Bhaskara, K.V.....	2372
Bebermeier, J.....	1921	Bhat, R.B.....	369, 540, 846, 1940 2121, 2373
Bechert, W.....	1469	Bhatia, K.G.....	43
Beck, C.J.....	686, 1012	Bhattacharya, A.P.....	2214
Beck, J.L.....	285	Bhattacharya, M.C.....	2468
Becker, P.....	2106	Bhattacharya, R.C.....	83, 101
Behring, A.G.....	2208	Bhave, S.K.....	2290
Beig, H.G.....	1806	Bi, Q.....	1124
Beiner, L.....	1984	Bickford, W.B.....	539, 650, 1446
Beissner, K.....	429	Biehn, K.....	1617
Belchamber, R.M.....	223	Bielak, J.....	1114, 1557, 2060 2284, 2285
Belingardi, G.....	2481	Bielawa, R.L.....	273
Beliveau, J.-G.....	728, 2363, 2524	Bieniek, M.P.....	1175
Bellman, R.....	1807	Bigret, R.....	2374, 2608
Belvin, W.K.....	411, 1546	Bijlani, M.....	1283
Belytschko, T.....	637	Bilazatian, P.....	439
Belytschko, T.B.....	1194	Bily, M.....	1854
Bendat, J.S.....	2401	Binder, M.C.....	2449
Bendiksen, O.O.....	1932, 2128	Bingham, B.L.....	2503
Bendimerad, M.F.....	1387	Birdsall, T.G.....	160
Benedetti, G.A.....	417	Birman, V.....	123, 825, 1587
Benedettini, F.....	2454	Bitnbaum, G.....	867
Bengisu, M.T.....	2348	Bishop, D.E.....	572
Benham, R.A.....	327	Bishop, R.E.D.....	91, 2059
Bennett, J.G.....	1179, 1195, 2085	Biswas, S.....	1496
Cennett, R.H.....	1348	Black, J.D.....	1033
Bennett, R.M.....	791	Blacker, T.D.....	1831
Benson, D.J.....	988, 2038	Blakney, D.F.....	570
Benson, M.W.....	1071	Bland, S.R.....	679
Bentley, D.E.....	1342, 2379	Blanding, J.M.....	1861
Bentley, S.B.....	529	Blech, J.J.....	1322
Bentsman, J.....	737, 1807	Blessen, D.A.....	2224
Benz, A.D.....	1705	Block, P.J.W.....	797
Bergman, L.A.....	65, 264, 890, 1312 1416, 1425, 1468	Bloemhof, H.....	350, 1625
Bergman, L.A.....	890	Boarer, L.J.....	2083
Berkay, H.O.....	628	Boden, H.....	1614
Berman, A.....	575, 1357, 1503	Bodlund, K.....	954
Berman, A.S.....	1365	Boentgen, R.R.....	2208
Bernal, M.J.M.....	260	Bofilios, D.A.....	2410, 2502
Bernard, J.E.....	1695	Bogy, D.B.....	2292, 2295
Bernard, P.....	1783	Bohlender, D.A.....	2264
Bernasconi, O.....	1696	Bohn, M.P.....	989
Berner, D.E.....	561	Boisson, C.....	1055, 2392
Bernhard, R.J.....	431, 2127, 2549	Boisvert, J.E.....	467
Bernitsas, M.M.....	30, 1540, 2151		

Bokaiian, A.....	1093	Buffa, J.....	1086
Boldman, D.R.....	1563	Buffinton, K.W.....	1969
Bolleter, U.....	171	Buffum, D.H.....	1563
Bonadero, A.....	785	Buggele, A.E.....	1563
Booker, J.F.....	1251	Buhariwala, K.J.....	1473
Borne, P.....	514	Buksa, E.J.....	2601
Bor-Jen, Lee.....	963	Burdick, R.B.....	2506
Bos, A.M.....	519, 932	Burkhard, A.....	494
Bosma, R.....	72, 1250	Burkhard, A.H.....	1833
Botnam, B.....	1260	Burns, D.W.....	746, 1933
Bouchard, M.P.....	314, 684	Burnside, O.H.....	80
Boucher, R.F.....	1094, 1095, 1610	Burrin, R.H.....	569
Bourdon, P.....	2287	Burrows, C.R.....	1
Bouwkamp, J.G.....	2335	Burrows, C.R.....	1938
Bovenzi, M.....	1017	Burton, T.D.....	2099
Boyd, L.S.....	599	Busenhart, M.....	2002
Bozorgnia, Y.....	1634, 1888	Bush, S.H.....	780
Braaksma, B.L.J.....	1844	Butler, B.P.....	2423
Bradburn, J.H.....	370	Butler, D.....	831
Bradley, A.J.....	1911	Butler, T.A.....	1195
Branco, C.M.....	1115	Button, M.R.....	2430
Brandon, J.....	1355	Butuman, V.....	973, 1019, 1020
Brandon, J.A.....	1334	Butzel, L.M.....	996
Branstetter, L.J.....	1805, 2051	Bux, S.L.....	1414
Bratosin, D.....	966	Buyukozturk, O.....	1146
Braun, S.....	1665	Buzdugan, Gh.....	965, 969
Brazier-Smith, P.R.....	831	Byrne, J.E.....	564
Brepta, R.....	3, 2231	Byrne, T.P.....	2442
Bresk, F.C.....	2333		
Breve, D.E.....	1744	- C -	
Briassoulis, D.....	1528	Cabelli, A.....	148, 421, 861
Brillhett, R.....	2542, 2545		1296, 1449
Brindeu, L.....	2048	Caboz, R.....	736
Brindley, J.....	1698, 2185	Cacko, J.....	1854
Brinkman, B.A.....	2322	Cackovic, D.L.....	2580
Brinkmann, K.....	490	Cacuci, D.G.....	2145, 2146
Britt, J.R.....	1306	Caesar, B.....	2359
Brock, L.M.....	2196	Caflisch, R.E.....	1964
Brockman, R.A.....	1098	Caggiano, J.L.....	1677
Broer, H.W.....	1844	Cai, Guoqiang.....	1656
Brokenshire, R.E.....	914	Calder, C.A.....	66
Brooker, M.J.....	70	Calderale, P.M.....	102
Brooks, R.P.....	385	Caltagirone, J.P.....	461
Broseby, T.G.....	1750	Campbell, R.D.....	989
Brouwers, J.J.H.....	1905	Campbell, T.G.....	817
Brown, A.L.....	53	Campbell, W.R.....	1136, 1137
Brown, D.L.....	904, 1690, 2209 2317, 2420, 2572	Candel, S.M.....	2250
Brown, J.A.....	968	Candir, B.....	2436
Brown, J.D.....	1911	Cao, X.S.....	2286
Brown, K.T.....	580, 885	Cao, Zhiyuan.....	1318
Brown, W.H.....	2248	Cao, Zhi-Yuan.....	141
Brubaker, R.L.....	1548, 1549	Capecchi, D.....	889
Bruneau, A.M.....	1624	Carcano, R.....	2475
Brunelle, J.....	2287	Card, M.F.....	1266
Brussat, T.R.....	1121	Carden, H.D.....	1223
Bryant, M.D.....	379	Carey, W.M.....	1632
Bucher, U.A.....	1827	Carne, T.G.....	1828, 2228
Buckle, I.G.....	811, 2431	Carnes, B.L.....	186
Buechler, M.....	233	Carney, K.S.....	1600

Carr, I.....	1455	Chen, C.R.....	1564
Carr, W.E.....	993	Chen, D.....	99
Casadei, F.....	2614	Chen, Huai.....	2193
Caseiro, C.A.....	1395	Chen, H.Q.....	1717
Casey, N.F.....	1674	Chen, Jay-Chung.....	323
Cassenti, B.N.....	898, 2509	Chen, J.....	503
Castagna, J.....	2258	Chen, J.C.....	1008
Castelli, R.....	280	Chen, J.K.....	406, 422
Castner, W.L.....	232	Chen, J.-W.....	1645
Cathers, B.....	2272	Chen, Kecheng.....	2301
Cawley, P.....	1664	Chen, L.C.....	1238
Cazier, F.W.....	1726	Chen, Meng Luo.....	2338
Celep, Z.....	731, 1270	Chen, Ping.....	2512
Cempel, Cz.....	917	Chen, P.C.T.....	836
Cerv, J.....	3	Chen, Qinghua.....	1656
Cha, J.H.....	1292	Chen, R.T.N.....	38
Chadmail, J.F.....	756	Chen, Shao-ting.....	1654
Chakrabarti, A.....	773	Chen, Shoei-Sheng.....	644
Chakrabarti, S.K.....	562, 646	Chen, Su-huan.....	2302
Chalhoub, B.G.....	2184	Chen, S.S.....	52, 651, 856, 2245
Chambless, D.....	129	Chen, T.-Y.....	2556
Chamis, C.C.....	94	Chen, Wen-Hwa.....	510
Chan, A.H.C.....	1773	Chen, W.J.....	1867
Chan, K.S.....	80	Chen, W.-H.....	1328
Chan, R.K.....	2195	Chen, Yen-Sen.....	577
Chandra, B.....	1522	Chen, Y.Y.....	1124
Chandra, D.....	2569	Chen, Zhongyi.....	2518
Chandrasekaran, K.....	399	Cheng, A.H.-D.....	2144
Chandrasekharappa, G.....	2463	Cheng, Chii-Ming.....	291
Chang, C.H.....	608	Cheng, C.....	1684
Chang, I.C.....	2355	Cheng, C.A.....	1365
Chang, I.-J.....	1448, 2252, 2266	Cheng, F.Y.....	1889
Chang, Jin.....	2515, 2567	Cheng, Xiang-sheng.....	1602
Chang, K.T.....	1717	Cheng, Yaodong.....	2360
Chang, Liang-Wey.....	822	Cheng, Yu-ren.....	201
Chang, P.C.....	1177	Cheng, Y.W.....	203, 1116
Chang, Shyue-Bin.....	815	Chenoweth, J.M.....	2008, 2009
Chang, S.B.....	68	Cherfaoui, M.....	207
Chang, Tai-Ping.....	1380	Cherng, J.-S.....	1328
Chang, Y.M.....	557	Chester, C.V.....	184
Chang, Y.W.....	297	Cheu, T.C.....	2349
Chang-qing, Du.....	1191	Cheung, Y.K.....	141, 614, 615, 1773
Chao, A.W.....	24	Chi, Cheng-Ching.....	887
Chapman, D.A.....	1409	Chi, M.....	543
Chapman, D.M.F.....	1304	Chia, C.Y.....	848, 1056
Chapman, I.....	1957	Chia, Tien-Li.....	1504
Chapman, J.R.....	831	Chiba, M.....	1443
Charek, L.T.....	1026	Chijiwa, K.....	542
Chargin, M.....	509, 1356	Childs, D.W.....	85, 1754, 1961
Charlie, W.A.....	456		2452, 2453
Charnley, T.....	649	Childs, M.E.....	660
Charron, F.....	2416	Chilson, G.F., Jr.....	2166
Chaskelis, H.H.....	1142	Chim, E.S.-M.....	697, 2064, 2291
Chattopadhyay, A.K.....	1941	Chino, Akira.....	1313
Chaturvedi, S.K.....	1110	Chiriacescu, S.T.....	1021
Chawla, A.....	2256, 2519	Chitu, D.....	981
Cheema, R.A.....	1554	Chiu, A.N.L.....	763
Chen, A.T.F.....	766	Cho, D.....	1238
Chen, Cheng-Hsing.....	551	Choi, DooWhan.....	33
Chen, C.....	745	Chona, R.....	271

Chonan, S.....	130, 381, 1280	Cook, C.P.....	1700
 2206, 2461	Cook, S.A.....	920
Chopra, A.K.....	295, 553, 762	Cooper, J.E.....	2528
	962, 982, 983	Cooper, J.F.....	82
 1525, 1526, 1718	Cooperider, N.K.....	257
Chory, A.....	1368	Coppolino, R.N.....	1675, 2163
Chou, C.-M.....	2530	Cops, A.....	585
Chou, Pei Chi.....	2129	Corey, C.A.....	1837
Choudhary, B.K., Jr.....	1605	Corley, W.G.....	2026
Chouychai, T.....	2334	Cornell, C.A.....	1847
Chow, L.C.....	1474, 2225	Corsain, G.....	663
Chow, Y.K.....	22	Cortinez, V.H.....	2459, 2467
Chretien, J.F.....	207	Cottin, N.....	2358
Christensen, E.R.....	49, 730	Coussy, O.....	14
Christensen, O.....	2393	Cover, L.E.....	989
Christiano, P.....	1892	Coy, J.J.....	1033
Chrysos, L.....	622	Craggs, A.....	2018, 2380
Chryssostomidis, C.....	97, 1588	Craig, R.R.....	1327, 1331, 1332
Chu, Chien-Tsun.....	1388	Craig, R.R., Jr.....	2349
Chu, Fei Hon.....	2166	Crandall, S.H.....	837
Chu, F.H.....	2556, 2568	Crawley, E.F.....	276, 1010, 1406
Chu, K.H.....	1175, 1205, 1707	Creighton, B.M.....	268
Chu, M.L.....	1458	Cretu, S.....	899
Chu, T.C.....	225	Crocker, M.J.....	694, 1086, 1107
Chuanren, Qui.....	1222	Crockett, L.K.....	232
Chui, Y.H.....	1235	Crooker, T.W.....	602
Chung, H.....	98	Croome, D.J.....	627
Chung, In Sung.....	1157, 1172	Crowe, E.....	1708
Chung, J.S.....	25	Crowe, R.D.....	920
Chung, K.R.....	1694	Crowley, J.....	2317
Chung, Ming-Ping.....	420	Crowley, J.M.....	830
Chung, T.J.....	465	Crowley, P.....	1751
Cies, J.M.....	2581, 2595	Crowley, S.M.....	2572
Cifuentes, A.O.....	760, 959	Cruz, E.....	1381
Cioara, T.....	1243, 2073	Cruz, E.F.....	1525, 1526
Citerley, R.L.....	509	Cuccio, J.....	1751
Clarkson, B.L.....	580, 885	Culshaw, B.....	1132
Claussen, U.....	484	Cummings, A.....	1448, 1779, 2252
Clauwaert, C.....	1178		2266
Clemente, J.L.M.....	1500	Cummings, W.M.....	270
Cloud, D.J.....	1846	Cunniff, P.F.....	1465
Clough, D.P.....	548	Cunningham, F.M.....	121
Clough, R.W.....	139, 764, 1717	Cunningham, R.E.....	888
Coates, R.C.....	2191	Curran, D.R.....	1123
Codaccioni, J.P.....	736	Curreri, J.....	2398
Coe, H.H.....	1253, 1936	Curti, G.....	606
Coe, T.J.....	306	Cuschieri, J.M.....	541
Coffinal, G.....	2190	Cutts, D.G.....	898
Cohen, H.....	116	Cveticanin, L.J.....	1515
Cohen, R.....	944	Czuchaj, J.....	395
Cohen, R.L.....	994		
Cojocaru, E.....	967		
Collins, M.P.....	223		
Colton, D.....	1303, 2031	- D -	
Combescure, A.....	987		
Connon, W.H., III.....	2579		
Conolly, B.W.....	1852		
Constantinescu, C.R.....	1022		
Constantinescu, I.....	1260		
Constantinou, M.C.....	807, 1018		

Daabdin, A.....	1706
Dacunha, N.M.C.....	34
Dadkhah, M.S.....	213
Dahl, M.D.....	1299
Dai, De Pei.....	2494
Dai, D.P.....	2286
Daimaruya, M.....	1641

Dakoulas, P.....	1534	Demirbilek, Z.....	147
Dakoulas, P.C.....	1391	Denham, R.N.....	1631
Dalamangas, A.....	630	Denisenko, N.....	452
Dalan, G.A.....	994	Denman, E.D.....	1394
Dallriva, F.D.....	2041	Denman, H.H.....	508
Dalton, E.C.....	1101	Deobald, L.R.....	1106, 2223
Danek, O.....	269, 1824	Der Hagopian, J.....	274
Daniel, I.M.....	1481	der Kiureghian, A.....	940
Daniel, J.....	1891	Derham, C.J.....	809
Daniel, J.I.....	2026	Dermitzakis, S.N.....	1460
Daniel, W.J.T.....	1799	DeRuntz, J.A.....	682
Daniels, E.F.....	999, 1215	Deruyttere, A.....	1117
Darbre, G.R.....	1532	Desai, C.S.....	1529
Dardano, R.....	2481	Desai, P.V.....	2019
Dardy, H.D.....	158, 1287	DeSanto, D.F.....	556
Darts, J.....	1226, 1227	Desaulnier, W.E., Jr.....	2449
Das, A.....	1005	Desrochers, A.A.....	1738
Das, B.....	2220	Desse, J.M.....	880
Dass, W.C.....	1899, 1900	DeVor, R.E.....	949
Dat, R.....	2411	deV Batchelor, B.....	1659
Date, C.G.....	1043	DeWilde, W.P.....	2464
Datta, B.N.....	2385	DeWinne, J.....	2584
Datta, S.K.....	1108, 1447	Dexter, R.J.....	1120
Daugherty, R.H.....	304	De-jun, Wan.....	1158
Dauphin-Tanguy, G.....	514	Dhar, B.....	174
Davani, D.....	2508	Dhar, D.....	2371
David, E.A.....	170	Dhoopar, B.L.....	824
David, J.W.....	272, 1862	Di Paola, M.....	1088
David, M.....	980	Di Sciuva, M.....	1990
Davidson, D.L.....	1120	Diarra, C.M.....	1132, 1233
Davie, N.T.....	495	Diaz-Jimenez, A.....	729
Davies, H.G.....	1466	Dideron, D.....	468
Davies, P.....	1663	Diebold, J.W.....	840, 1710
Davis, B.C.....	1462	Dietmann, H.....	474
Davis, L.C.....	157	Dietz, C.P.....	13
Davis, M.R.....	2262	Dill, J.F.....	2444
Davy, J.L.....	2316	DiMaggio, F.L.....	135, 1207
Day, A.H.....	2150	Dimarogonas, A.D.....	1749, 2186
Day, W.B.....	275	Dimas, D.J.....	2280
De, S.....	107	Ding, Kui-yuan.....	2370
de Azevedo, J.J.R.T.....	457	Ding, Shi.....	1177
de Billy, M.....	1759	Dion, J.L.....	2032
de Pater, A.D.....	813	Ditt, B.....	67
de Silva, C.W.....	721	Dirusso, E.....	1753
De Vis, D.....	2546	Ditlevsen, O.....	1768
De Winne, J.....	2592	Dmytrow, D.A.....	9
Deane, G.B.....	869	Dobbs, N.....	461
Dearth, D.R.....	714	Dobson, B.J.....	229, 2525
DebChaudhury, A.....	891	Doctor, S.R.....	780
DeBejar, L.A.....	1382	Doege, E.....	339
DeBondt, M.....	1117	Dogan, M.....	595
Decha-Umphai, K.....	127, 1046	Doht, G.....	1352
Dede, M.....	461	Doi, Masahiro.....	1170, 1518, 1875
Deepak, D.....	2437	Dokanish, M.A.....	653
DeHoff, B.S.....	526	Domaszewski, M.....	388
DeJong, R.G.....	368	Dominguez, J.....	1714
Delage, P.....	707	Dominic, R.J.....	278, 314
Delgado-Saavedra, H.E.....	1482	Don, C.G.....	177
Delinic, K.....	2428	Done, G.T.S.....	743
Demetriu, S.....	971	Dong, S.B.....	1441, 1896

Dongping, L.....	1986	Eichenlaub, J.A.....	470
Donnelly, R.P., Jr.....	1915	Eidinger, J.M.....	803
Dooley, W.T.....	2478	Eischen, J.W.....	1662
Doorly, D.J.....	1244	Eisenberger, M.....	833
Dornfeld, D.A.....	253, 916	Ejezie, S.U.....	294
Dossing, O.....	2318, 2522	Ejiri, H.....	46
Dove, R.C.....	1179, 2085	Eken, F.....	2455
Dowell, E.H.....	610, 1054, 1559 1764, 2283, 2466	Ekhelikar, R.K.....	1767
Dowling, M.J.....	1186	El Khatib, A.....	2170, 2314, 2435 2604
Downes, J.....	662	El Sayed, A.....	2604
Downs, B.....	1976	El Shahawi, M.....	1659
Doyle, G.R., Jr.....	1728	El Shahawi, M..A.-H.....	1265
Doyle, J.F.....	77, 1096	Elbestawi, M.A.....	2609
Dragos, L.....	794, 884	Elgamal, A.-W..M.....	774, 775, 984
Draisey, S.....	2363	Elia, A.....	785
Drake, M.L.....	314, 472, 684 1002, 1113	Elishakoff, I.....	825, 1808
Dressman, J.B.....	85	Ellen, C.H.....	866
Drew, M.....	695	Eller, A.I.....	165, 166
Dreyer, W.....	2313	Ellinas, C.P.....	563
Driels, M.R.....	183	Ellington, B.....	755, 1378
Drumm, E.C.....	674, 1529	Elliott, L.....	1698, 2185
Du, Qingxuan.....	485	Elliott, S.J.....	662
Duan, Z.P.....	1662	Ellis, D.D.....	1304
Dubey, R.N.....	2184	Ellison, B.....	1633
Dubigeon, S.....	2117	Ellison, J.F.....	1231, 1726
DuBois, T.....	756	Ellyin, F.....	1925
Dufour, R.....	274	Elmadany, M.M.....	2241
Duke, J.C., Jr.....	1777	Elmalah, E.....	2586, 2587, 2593
Dumanoglu, A.A.....	15	Elmer, K.....	941
Dumelin, M.B.....	2594	Elrod, D.....	2453
Dumit, P.C.....	1066, 1182, 1281 1603, 1604, 1776 2215	Ely, R.A.....	997
Dunavant, D.A.....	1684	Elzanowski, M.....	1464, 2037
Dunwoody, W.E.....	1179	El-Raheb, M.....	136, 137, 1286
Dupuis, C.....	144	El-Wardany, T.I.....	2535
Dusseau, R.A.....	1884	Eman, K.F.....	948
Dwyer, R.F.....	37	Embling, L.V.....	1252
Dyer, R.....	1090	Endebrock, E.G.....	1179
Dykhuizen, R.C.....	986	Endo, Mitsuru.....	1871
Dyrbye, C.....	1887	Endo, M.....	2122, 2477
Dzhupanov, V.A.....	654	Engblom, J.J.....	632
Dzielski, J.E.....	784	Engel, Z.....	1872
D'Spain, G.L.....	1790	Engelke, V.H.....	758

- E -

Eakes, R.G.....	2171	Engelstad, M.....	129
Eastwood, P.G.....	241	Engja, H.....	517
Ebeling, K.J.....	1305	Enke, N.F.....	208
Ebert, K.....	1734	En-Sheng, Chen.....	1146
Ebrahimi, N.D.....	2118	Epstein, M.....	1464, 2037
Eckblad, D.M.....	326	Erasmus, P.J.....	1622
Edberg, D.L.....	1919	Ercoli, L.....	1052, 1427, 1433 1995
Edelstein, W.S.....	856, 2245	Erhard, A.....	1817
Edwards, J.W.....	679	Ericsson, L.E.....	1125
Edwards, P.R.....	1226, 1227	Eriksson, L.J.....	2028
Ehsani, M.R.....	1590, 1591	Ertas, A.....	310
		Ertepinar, A.....	1980
		Ertugrul, M.G.....	161
		Eshleman, R.L.....	1129, 1143
		Esin, A.....	1118
		Eslambolchi, H.....	488

Esparza, E.D.....	2040	Fischer, F.J.....	33
Esposito, E.....	2250	Fischer, U.....	2111
Etison, I.....	1037, 1408, 1962	Fisher, J.W.....	1036
	2451	Fitzmorris, D.J.....	348
Ettema, R.....	1723	Fitzpatrick, J.A.....	415
Etter, C.L.....	340	Fitzpatrick, M.....	55
Eugen, L.....	976	Flaherty, J.E.....	836
Evensen, H.....	2306	Flanigan, C.C.....	2313
Everett, W.D.....	318	Flashner, H.....	1822
Eversman, W.....	574, 1463, 1784	Fleeter, S.....	1029, 2375
	2030	Fleischer, F.....	57
Everstine, G.C.....	1609	Fleischer, H.....	178, 1454
Evransel, C.A.....	1319	Fleischman, T.S.....	211
Ewans, K.C.....	437	Fleming, D.P.....	1323, 1573, 2445
Ewing, R.D.....	287	Foiles, W.C.....	2607
Eydeland, A.....	266	Fok, Ka-Lun.....	1389, 1718
- F -			
Fabunmi, J.A.....	688, 2414	Foley, M.J.....	2126
Faby, D.R.....	2605	Foltz, J.V.....	1440
Fafitis, A.....	455	Fomo, K.....	2139
Fahmy, M.N.....	718	Fontana, R.R.....	360
Fahs, A.A.....	1493	Foote, K.G.....	168
Falk, S.....	90	Forouhar, F.....	1444
Fallou, S.N.B.....	1202	Forster, N.H.....	2444
Fan, Yong-Fa.....	777	Forys, A.....	2200
Fancher, M.F.....	675	Fourney, W.L.....	271
Fang, Dan Ping....	2397	Fox, C.H.J.....	95, 850
Fang, M.C.....	1212	Fox, N.....	436
Fang, Tong.....	1688	France, D.....	1366
Fang, T.....	2304	France, D.M.....	986
Fanous, F.....	28	Francois, E.....	1642
Farassat, F.....	1742	Franklin, D.E.....	2199
Farley, G.L.....	1053	Frarey, J.L.....	2605
Fathi, A.M.....	1263	Fratello, D.J.....	173
Faulkner, M.G.....	2310	Freed, A.D.....	208
Favaloro, S.C.....	1344, 1835	Freedman, M.I.....	48
Favour, J.D.....	1832	Freestone, J.W.....	239
Feijoo, R.A.....	1067	Frehlich, R.G.....	261
Feit, D.....	110, 169	Freund, L.B.....	2217
Felsen, L.B.....	111, 1661	Friberg, P.O.....	828
Fenech, H.....	1596, 1769	Friedmann, P.....	1228
Feng, N.S.....	2052	Friedrich, G.....	1402
Feng, W.Q.....	499, 2303, 2307	Friesel, M.A.....	506
Feng, Zhendong.....	2387	Fritzen, C.-P.....	1691
Fenves, G.....	295, 553, 982	Frohrib, D.A.....	521
	983	Frotiep, R.....	2413
Ferrari, G.....	280	Fu, Chung C.....	1200
Ferri, A.A.....	610, 1810	Fu, Hao-Jen.....	1370
Ferro, G.....	788	Fuchs, H.....	1817
Fiedler, K.....	1562	Fuh, J.S.....	1503
Fields, D.....	2257	Fuhua, Ling.....	1648
Fields, J.M.....	333, 336	Fujii, S.....	1560
Figueroa, L.....	768	Fujii, T.....	1568
Filippi, P.....	259	Fujikawa, T.....	511, 2533
Filippou, F.C.....	1580	Fujimoto, Ichiro...	1246, 1247, 1248
Finch, R.D.....	1343	Fujimoto, Toshiro.....	1516
Fink, R.G.....	158, 1287	Fujita, Katsuhisa.....	1781
Firestein, G.J.....	565	Fujiwara, M.....	282
		Fujiwara, T.....	243
		Fukahori, M.....	1572
		Fukano, T.....	2123

Fukuda, Toshio.....	1547, 1880	Gerber, J.D.....	2553
Fukuhara, H.....	2081	Gerritsen, E.....	2138
Fukumoto, Yuhshi.....	1050	Gershfeld, D.A.....	165, 166
Fukumoto, Y.....	638	Geyer, K.....	1358
Fukuwa, N.....	1713	Ghabrial, M.A.E.....	404
Fuller, C.R.....	40, 1544, 2155	Ghafory-Ashtiani, M.....	1520, 1533
Furuhashi, Takeshi.....	1258	Ghanaat, Y.....	1717
Furusawa, M.....	2557	Ghoneim, H.....	1554
Fuwano, M.....	2	Ghosh, A.K.....	799, 1975
Fyfe, K.....	2365	Ghosh, M.....	1496, 2207

- G -

Gabler, H.C., III.....	303	Gibb, J.....	2485
Gad, E.H.....	366	Gibbs, B.M.....	1405, 1993
Gadala, M.S.....	2241, 2442	Gibson, R.F.....	1106, 2223
Gadd, P.....	722	Giergel, J.....	1856
Gade, S.....	1668	Gifford, L.N.....	993
Gaffer, H.....	2170, 2435	Gilan, A.....	2408
Gaffney, E.S.....	968	Gilbert, P.....	241
Gagnepain, J.J.....	1820	Gilbey, J.....	2521
Galant, D.....	509	Giles, G.L.....	2409
Galea, S.....	1218	Gill, S.J.....	602
Gallus, H.E.....	352	Gillespie, T.D.....	590
Galy, P.....	468	Gindy, S.S.....	222
Gambhir, M.L.....	2188	Ginters, K.-H.....	2016
Gandhi, M.L.....	1182, 1776	Gion, E.J.....	875
Ganesan, N.....	402, 633, 636	Giovanola, J.H.....	700
	1775, 1943, 1944	Girard, A.....	2043, 2049
	1996	Giuliani, J.L., Jr.....	1797
Gangfu, W.....	2131	Gladwell, G.M.L.....	1349
Gantayat, A.....	757	Glaninger, P.....	2080
Ganz, I.....	1769	Glaser, H.....	2415
Gao, Lin.....	1902	Glass, I.I.....	1800, 2042
Gao, Pinxian.....	1164	Glegg, S.A.L.....	92
Gao, Qiang.....	2395	Glienicker, J.....	1652
Gao, Y.C.....	2065	Glockler, O.....	918
Gaonkar, G.H.....	942	Gluck, R.....	1104
Garba, J.....	332	Goble, G.G.....	903
Garba, J.A.....	323	Goel, A.K.....	2153
Gardiner, D.S.....	1341	Goel, S.C.....	603
Gardner, T.G.....	1445	Goenka, P.K.....	71
Garg, V.K.....	1176, 1205, 1707	Gohar, R.....	594
Garro, A.....	2402	Goldberg, A.....	210
Gast, T.....	1131	Goldberg, H.....	2585
Gaught, T.M.....	229	Goldfracht, E.....	1992
Gaunaurd, G.C.....	140	Goldman, A.....	1218
Gauvin, R.....	1119	Golla, D.F.....	1476
Gazetas, G.....	1534	Gollbach, L.....	2257
Gazis, G.D.....	2507	Golovkina, A.B.....	654
Geiling, U.....	1371	Gomaa, F.R.....	2314
Geldmacher, J.....	67	Gonzales, A.....	2171
Gelos, R.....	1595, 2469	Goodyer, M.J.....	491
Genta, G.....	1362	Goonetilleke, R.S.....	2251
Gentili, H.....	1260	Goorjian, P.M.....	795
Geoffroy, P.....	987	Gopalan, T.V.....	604
Geoola, F.....	1093	Gorman, D.G.....	1061, 1062
George, A.R.....	68	Gorman, D.J.....	2470
George, M.K.....	2495	Gorman, V.W.....	2478
Gerasch, W.-J.....	1023	Goshorn, L.....	1423
		Gosiewski, Z.....	719

Goss, P.C.	2472	Guohao, Li	1177
Gottlieb, H.P.W.	1424	Gupta, A.D.	26
Gould, P.L.	963, 1472	Gupta, A.K.	125, 1420, 1782 1903, 1970, 1974 2489
Goyal, S.K.	2290		
Grace, N.F.	844	Gupta, B.K.	1396
Gracewski, S.M.	717, 2292, 2295	Gupta, N.K.	373, 938, 1637
Gradov, O.M.	1811	Gupta, P.C.	824
Graf, P.A.	314	Gupta, P.K.	2444
Granberg, R.H.	1071	Gupta, U.S.	1282, 1436
Granda, J.J.	528	Gurgoze, M.	1041, 1977
Grandhi, R.V.	1689, 1848	Guruswamy, G.P.	795
Granett, D.	2615	Gutierrez, R.H.	397, 847, 1057
Granneman, G.	2025	Guttalu, R.S.	930
Grassie, S.L.	776	Guyader, J.L.	1055, 2392
Green, I.	1037, 1408, 1962 2451	Guyomar, D.	1789
Green, P.L.	1013	Gvildys, J.	297
Green, R.E., Jr.	234	Gyori, I.	2021
Greenhalgh, R.	2020	Gysin, H.	2554
Greenhill, L.M.	539		
Greenwald, S.E.	145		
Gregory, D.L.	1805, 2465, 2548	- H -	
Greif, R.	2288	Haas, E.	860
Greimann, L.	28	Habault, D.	258, 663
Greitzer, E.M.	1508	Habermeier, J.A.	2173
Gridley, D.	1786	Hac, A.	586, 2176
Griefahn, B.	1920	Hadaegh, Y.	740
Griffin, J.H.	1114, 1361, 1557 1929, 1935, 2060 2284, 2285	Haddow, J.B.	2108
Griffin, M.J.	584	Hadjian, A.H.	804, 1633
Griffin, O.M.	1262	Haftka, R.T.	228, 1031, 1689 1848
Griffiths, P.J.	582		
Grigoriu, M.	1722, 2039, 2095	Hagedorn, P.	1994
Grindrod, K.J.	1249	Hagita, A.	1582
Grinfogel, L.	1411	Hagiwara, N.	357, 1242
Grinnell, S.E.	1462	Hahn, E.J.	196, 693, 2052
Grivas, D.A.	2105	Hahn, G.T.	902
Grochla, J.	2111	Hai, Y.	106, 1203
Grootenhuis, P.	1432	Haines, D.W.	1133
Groper, M.	78, 79	Haisty, B.S.	237
Gros, E.	1920	Hajela, P.	2157
Grossi, R.O.	1052, 2473	Hakala, M.K.	1208
Gruenberger, H.S.	2491	Hale, A.L.	264
Gruhl, S.	1617	Hall, A.	53
Grunseit, Z.	463	Hall, J.F.	1186, 1715
Gu, Jiali.	1868	Hall, M.	1788
Gu, Song-Nian.	2550	Hall, R.L.	767
Gu, Xue Min.	855	Hallauer, W.L., Jr.	228, 689, 2057
Gu, Yi.	2515, 2567	Halle, H.	2008, 2009, 2247
Guan, Bo Liang.	1258	Halleux, J.P.	2614
Guan, Fei.	2512	Halliwell, D.G.	70
Guang-fu, Wang.	1169	Halliwell, N.A.	241, 414, 2328
Gudmundson, P.	2563	Hallquist, J.O.	988, 2038, 2112 2113
Guedel, A.	668	Halpern, M.R.	1892
Gueraud, R.	806	Halvorsen, T.	147
Guerra Rosa, L.	1115	Hamazaki, Y.	2533
Guha, S.K.	1942	Hamdan, S.M.	256
Guicking, D.	1305	Hamdi, M.A.	2249
Guo, Xing-Huie.	2212	Hamed, M.A.	225
		Hamelink, J.	78, 79

Hamilton, R.F.	1750	Hawkins, G.F.	233
Hamma, G.A.	2591	Hawong, J.S.	213
Hammond, J.K.	296, 1537, 1663 1907, 2149, 2279 2315	Hayashi, K.	1274, 1647
Hammond, T.A.	578	Hayden, R.E.	1791
Hamrock, B.J.	1744	Hayes, C.D.	2423
Hamstad, M.A.	1785	Haynes, F.D.	1904
Han, D.C.	2132	Hays, W.D., Jr.	1909
Han, Eth-Chung	2212	Hayward, J.	64
Hanawa, T.	50	Hayward, J.L.	39
Hancock, R.N.	493	He, Chang-An	2550
Handleton, R.T.	451	Head, R.E.	361
Handy, C.R.	726, 727	Heap, N.W.	434
Hannover, G.E.	1921	Hebbale, K.V.	819
Hansen, H.S.	2237	Heckl, M.	2016
Hansen, J.S.	254	Hedrick, J.K.	784, 787, 1238
Hansen, K.-H.	2597	Hegr, J.	2197
Hanson, D.B.	11	Heidebrecht, A.C.	23, 1197
Hanson, R.D.	603	Heins, C.P.	1177
HaQuang, N.	864, 1471, 2353 2486	Heitkamper, W.	1275
Hara, F.	375	Heitman, K.E.	1541
Harajili, M.H.	618	Heitzig, J.H.	1921
Haran, S.	1343	Helfrich, T.M.	318
Hardie, D.J.W.	850	Hellman, R.P.	581
Harding, R.	1005	Helsel, R.	2306
Hardy, C.	2287, 2490	Hemphill, R.R.	340
Hardy, S.J.	89	Hendricks, S.L.	1512, 1866
Harichandran, R.S.	1635	Heng, R.B.W.	448
Hariharan, S.I.	2496	Henkel, E.-O.	782
Harmanny, A.	1310	Henricks, W.	331
Harnchoowong, S.	2450	Heppler, G.R.	1439
Haroun, M.A.	852	Herklotz, G.	155, 665, 666
Harris, R.E.	653	Hernried, A.G.	185, 2109
Harris, T.A.	73	Herrmann, G.	1662
Harrison, J.H.	2400	Herron, D.L.	286
Harrison, R.F.	296, 1537, 1907 2149	Hersey, J.B.	157
Hart, G.C.	2425	Herting, D.N.	1330
Hartt, W.H.	1721	Hess, R.W.	317
Harwood, N.	270	Hews-Taylor, K.J.	2262
Hasegawa, Eiji	1772	Heylen, W.	2326
Hasegawa, E.	1989	Hibner, D.H.	818
Hasegawa, Mitsuhiko	1192, 1193	Hicks, J.	2536
Hasegawa, M.	1713	Hidayetoglu, T.	2348
Hashimoto, Hiroyuki	1316, 1317	Hiei, Makoto	1511
Hashimoto, H.	1254, 1443	Higashi, M.	1506
Haskell, R.	2426	Hildebrandt, J.G.	2018
Haslim, L.A.	2438	Hill, D.E.	1918
Haslinger, K.H.	1829	Hill, E.v.K.	826
Hassiotis, S.	2505	Hilmy, S.I.	625
Hastrup, O.F.	1852	Hinchey, M.J.	564
Hata, O.T.	152	Hindson, W.S.	38
Hatake, S.	2072	Hinga, S.	1926
Hatamura, Y.	542	Hino, J.	702
Hattori, K.	1567	Hintergraber, M.	778
Haug, E.J.	2046, 2104, 2174 2356	Hiramatsu, T.	2044
Hauser, J.A.	602	Hirata, T.	154
		Hireath, M.S.	525
		Hiromoto, D.	210
		Hirose, S.	245
		Hisada, T.	18
		Hisley, D.M.	875

Hitchcock, K.N.	240	Huang, J.T.	1521
Hnat, W.P.	2007	Huang, Liping	2301
Hodges, C.H.	640, 641, 643	Huang, Nai-shi	201
Hodges, D.H.	1042, 1162	Huang, S.N.	1241
Hoff, C.J.	30, 566	Huang, T.C.	2201, 2307
Holban, S.	1020	Huang, Yen-How	696
Holler, R.	1576	Huang, Z.	658
Hollerbach, W.	859	Hubbard, J.E.	1040
Hollis, P.	1945	Hubbard, J.E., Jr.	360
Holmer, C.I.	41, 1001	Hudak, S.J.	1120
Holmes, P.	265	Hudak, S.J., Jr.	80
Holmes, R.	595, 1946	Hudspeth, R.T.	1720
Holtmann, H.	352	Huffmann, G.K.	812
Holzapfel, W.	1736	Hughes, P.C.	320, 1476
Holzdeppe, D.	2415	Hui, D.	400
Holzer, F.	428, 2538	Hui, W.H.	316
Holzneimer, H.-G.	475	Humen, V.	1795
Honda, Y.	747	Humphrey, V.F.	628
Hong, Feng	453	Hundal, M.S.	348, 589, 2564
Hong, H.-K.	109	Hunt, D.L.	1336, 2161, 2542
Hong, Jin Sun	2384		2545
Hong, Rex Chin-Yih	354	Hunter, K.W., Sr.	2240
Hong, S.J.	525	Huo, Shaocheng	2133
Hong, Y.S.	1210	Hurst, P.W.	1357
Honma, T.	1536	Huseyin, K.	262
Hopstone, P.	2408	Hutchins, D.A.	1084
Horacek, J.	2230	Hutchinson, J.R.	1586
Horenberg, J.A.G.	1058	Hutson, R.L.	2367
Hori, Y.	1947	Hutton, P.H.	505, 506, 915
Hoschl, C.	2198	Hutton, S.G.	1127, 1548, 1549
Hoshiya, Masaru	1845	Hwang, H.	1719
Hoskins, C.B.	2582	Hyde, T.H.	89
Hosokai, Hidemi	1547		
Houjoh, H.	1954		
Houston, R.	394		
Hounjet, M.H.L.	1731		
Houset, D.R.	1952		
Housner, J.M.	1234, 1546		
Howard, I.M.	2277		
Howe, M.S.	2024		
Howell, G.P.	1911		
Howgate, P.G.	209		
Howsman, T.G.	1332		
Hoyniak, D.	1029, 1741, 2375		
Hrovat, L.	283		
Hryniwicz, Z.	921		
Hsia, Y.	2259		
Hsiang-Chuan, Tsai	1240		
Hsieh, B.J.	1196		
Hsieh, J.-C.	626		
Hsu, C.S.	930		
Hsu, F.H.	193		
Hsu, N.N.	427		
Hu, Kuo-Kuang	1584		
Hu, Sav-Lon James	1685		
Hu, T.C. J.	1800		
Hu, Xuan Li	2494		
Hua, Chang-Tsan	478		
Huang, B.	862		
Huang, Dun-Pu	2552		
Iannuzzelli, R.J.	1360		
Iberle, K.	2299		
Ibrahim, R.A.	735		
Ibrahim, S.R.	1823, 2088		
Ichikawa, A.	1216		
Ichsan,	206		
Ida, H.	648		
Ifrim, M.	971, 977		
Igarashi, T.	446		
Igusa, T.	940		
Iida, Hiroshi	1507		
Iida, H.	76		
Iida, K.	1621		
Ikawa, H.	330		
Ikeda, Takashi	1511, 2376		
Ikeda, T.	1934		
Ikegami, R.	686, 1012		
Ikonomou, A.S.	808		
Ikushima, T.	1536		
Iliff, K.W.	524, 938		
Ilkhani-Pour, M.	832		
Imanishi, E.	511, 2533		
Inagaki, S.	1979		
Inamura, Toyoshiro	1687		
Inano, S.	1255		

- I -

Inger, G.R.	675	Jay, R.L.	746, 1933
Inman, D.J.	1097, 1680, 2395	Jefferys, E.R.	1211
	2439	Jendrzejczyk, J.A.	52, 651, 1292
Ino, Y.	1725		2245
Inoue, J.	195, 512, 536	Jeng, M.C.	1949
	2089	Jeng, V.	1924
Inoue, T.	2116	Jenkins, C.J.	1252
Inoue, Y.	2500	Jenkins, E.G.	239
Ioannides, E.	73, 1432	Jensen, D.L.	1007
Iordanescu, M.	2490	Jensen, K.	723
Irani, F.	2580	Jeon, G.J.	1394
Iravani, M.R.	1161	Jeong, G.D.	1461
Irie, Tsukasa	1192, 1193	Jermey, C.	790
Irie, T.	635, 648, 849	Jerome, E.L.	122
Irie, T.	1442, 1589, 2229	Jeter, J.W.	518
Irschik, H.	845	Jewitt, T.H.B.	248
Itwin, G.R.	271	Jezequel, L.	709, 1693
Itwin, P.J.	2264	Jha, S.K.	2439
Ishi, H.	357	Jha, V.K.	2416
Ishida, Katsuhiko	1180	Jiang, Jiann-Kuo	1453
Ishida, Yukio	1511, 2376	Jiang, Jie-Sheng	2550
Ishihara, S.	481	Jiang, Jinren	289, 453
Ishii, Hiroshi	1242	Jiang, J.	99
Ishii, K.	1711	Jiang, J.K.	432
Ishii, Susumu	1246, 1247, 1248	Jiang, Zikang	1561
Ishii, S.	2500	Jiao, Qunying	100
Ishikawa, T.	45	Jiguang, An	1222
Ismail, F.	2365	Jimbo, Y.	1923
Isogai, K.	46	Jin, D.	466
Issa, C.A.	1372	Jindal, A.K.	2188
Ito, Hiroshi	1192, 1193	Jingu, T.	1639
Ito, Yoshimi	1157, 1170, 1172	Jinnouchi, Y.	473, 536, 2089
	1518	Joachim, C.E.	492
Ito, Y.	751	Joannides, R.	1991
Iu, V.P.	614, 615	Johns, D.J.	677, 1283
Iwan, W.D.	771	Johnson, A.W.	287
Iwanami, K.	344	Johnson, C.D.	1105
Iwankiewicz, R.	1646	Johnson, C.E.	1750
Iwata, N.	2484	Johnson, C.P.	2349
Iwata, Y.	346	Johnson, D.W.	686
Iwatubo, T.	2116	Johnson, K.L.	776
Iyengar, N.G.R.	1431	Johnson, L.W.	1592
		Johnson, R.O.	611
		Johnson, W.	319, 358, 373
			1733

- J -

Jachman, J.J.	60	Johnston, R.A.	361
Jackson, C.	1747	Jones, D.I.G.	1035
Jacob, K.I.	1998	Jones, D.I.G.	476, 477, 895
Jacobs, P.A.	464		1321
Jacobson, B.A.	1744	Jones, D.J.	267
Jain, A.K.	839	Jones, H.W.	1084
Jain, R.K.	851, 1065	Jones, L.R.	2431
Jakub, M.	770	Jones, N.	1643
Jamaleddine, A.	1479	Jones, R.	2299, 2529
James, J.H.	2001	Jones, R.H.	506
Janisz, C.K.	914	Jones, R.L.	247
Jansen, U.	2071	Joo, G.	2021
Jansson, T.	1912	Joodi, P.M.	2143
Javidinejad, M.	2572	Jordan, G.R.	1130
Jaw, J.-W.	1782, 2489	Jospin, R.J.	1067

Ju, F.D..... 2606
 Juan, Y.C..... 608
 Juang, J.N..... 1418
 Juckenack, D..... 2382
 Judd, J.E..... 2537
 Junger, M.C..... 438
 Junkins, J.L..... 2571
 Jun-Hua, Chen..... 1168

-K-

Kaas, P..... 859
 Kaatzsch, U..... 1371
 Kaba, S.A..... 424
 Kabe, A.M..... 1156
 Kainins, A..... 1319
 Kaji, S..... 69
 Kajita, T..... 1778
 Kaladi, V..... 1072
 Kalaroutis, A..... 2261
 Kalmaz, E.E..... 2613
 Kalra, S.P..... 986
 Kamada, O..... 367, 2447
 Kamegai, M..... 877
 Kamga, T..... 2139
 Kamil, H..... 757
 Kamle, S..... 77, 1096
 Kammer, D.C..... 2313
 Kammer, N..... 1509
 Kampfe, W.R..... 327
 Kanai, Eriya..... 1313
 Kanda, Hiroshi..... 2551
 Kanda, H..... 2209, 2312
 Kaneta, M..... 1572
 Kang, B.S.J..... 213
 Kania, N..... 1618
 Kanik, U..... 835
 Kapania, R.K..... 1438
 Kapoor, S.G..... 949, 1876
 Kar, R.C..... 1585
 Karakostas, C.Z..... 1577
 Karamchandani, A..... 2239
 Karamcheti, K..... 2259
 Kareem, A..... 753, 754
 Kariotis, J.C..... 287
 Karius, D..... 733
 Karnopp, D..... 426
 Karthaus, W..... 1310
 Kashefi, I..... 1883
 Kashimura, H..... 2484
 Kathiresan, K..... 1121
 Kato, D.J..... 2253
 Kato, Masayoshi..... 1163
 Kato, M..... 1864, 1885
 Kato, Yoshio..... 1192, 1193
 Katsura, S..... 642
 Katyl, R.H..... 1821
 Katz, E..... 2587
 Katz, J..... 998
 Kauffman, R.R..... 322

Kaufman, A..... 355
 Kausel, E..... 1385
 Kawagoe, H..... 657, 2017
 Kawai, M..... 1647
 Kawai, Tatsoo..... 1267
 Kawase, H..... 1712
 Kawazoe, Yoshihiko..... 1167
 Kaza, K.R.V..... 12, 591, 1027
 Kearley, V.C..... 1235
 Keefe, R.T..... 329
 Keer, L.M..... 386, 1897
 Kehoe, M.W..... 1231, 1726
 Keith, W.L..... 734
 Kekridis, M.S..... 2151
 Kekridis, N.S..... 1540
 Kelkel, K..... 1994
 Keller, A.C..... 2599
 Keller, E.E..... 1917
 Keller, J.B..... 1796
 Keller, Y..... 1616
 Kelley, H.L..... 361
 Kelley, N.D..... 340
 Kelly, J.M..... 587, 685, 803
 809, 1240, 2424
 Kelly, T.E..... 2431
 Keltie, R.F..... 1780
 Keming, Sun..... 1902
 Kennedy, D..... 827
 Kennedy, J.B..... 844
 Kennedy, J.M..... 1194
 Kenner, V.H..... 1141
 Kensinger, S.G..... 1705
 Kerley, J..... 1009
 Kern, D..... 332
 Kern, W..... 716
 Kerong, Li..... 1579
 Kersey, A.D..... 219
 Kerstens, J.G.M..... 1058
 Kerwin, E.M..... 1111
 Kesavan, S.K..... 1458
 Keshavarzian, M..... 149
 Keskinen, R.P..... 1073
 Kessler, E..... 1597
 Khan, F..... 160
 Khan, N.U..... 1575, 1578
 Khatri, K.N..... 1066, 1281, 1603
 Khouri, B.R..... 522
 Khulief, Y.A..... 1457, 1651, 2345
 Khvingia, M.V..... 2045
 Kibblewhite, A.C..... 437
 Kiefer, J.E..... 263
 Kiefling, L..... 1165
 Kielb, R.E..... 403, 1600, 1840
 1929, 1930
 Kienholz, D.A..... 1105
 Kiger, S.A..... 459, 2041
 Kikuchi, K..... 2
 Kikuchi, T..... 46
 Kikushima, Y..... 63, 588, 2433
 2434

Kikushima, Yoshihiro.....	1879	Kojima, H.....	532, 2115
Kim, Chul Jung.....	483	Kokarakis, J.E.....	30
Kim, C.....	1752	Kolitsch, H.J.....	475
Kim, C.H.....	1212	Koller, M.G.....	2002
Kim, H.W.....	2179	Kolsch, I.....	2167
Kim, KiBong D.....	2369	Kolsky, H.....	1271, 1640
Kim, K.B.....	1865	Kondou, Takahiro.....	1516
Kim, K.S.....	2204	Kondou, T.....	366, 2093
Kim, K.-S.....	1122	Kong, Fannien.....	1666
Kim, R.Y.....	217	Konishi, T.....	146
Kim, S.H.....	2234	Kopff, P.....	2543
Kim, S.S.....	2351, 2352	Korenev, B.G.....	1024
Kim, Y.D.....	534	Korpert, K.....	338
Kim, Y.-H.....	1576	Kosawada, T.....	372, 1289
Kimura, K.....	412	Koss, L.L.....	748
Kimura, M.....	2114	Kot, C.A.....	1196
Kimura, T.....	2092	Kotera, Tadashi.....	1269
Kirchman, E.J.....	2419	Kotera, T.....	192, 2044
Kiryu, K.....	1407	Kothari, L.S.....	2213
Kishi, T.....	657, 2017	Kounadis, A.....	2210
Kishima, A.....	922	Kounadis, A.N.....	1981
Kiso, M.....	1676	Koung, R.T.F.....	2530
Kitano, Y.....	371	Kouvaritakis, B.....	1846
Kitaoka, S.....	482	Kovacevic, M.....	2340
Kitis, L.....	1636	Koval, L.R.....	574
Kitsios, E.E.....	1094, 1095, 1610	Kowalczyk, W.....	748
Kiureghian, A.D.....	1794	Kraemer, T.....	2558
Kjell, G.....	1793	Kramer, E.....	1126
Kjellberg, A.....	342	Krause, W.....	1051
Klahs, J.W.....	2289	Krause, W.....	155, 665, 666
Klamecki, B.E.....	883		978, 1051
Klauer, A.....	1486	Krauss, H.....	1543
Klein, L.S.....	877	Krauthammer, T.....	17
Klein, R.....	2408	Krawinkler, H.....	613
Klein, S.K.....	1816	Kreitlow, H.....	67
Kleine-Tebbe, A.....	908	Kriegsmann, G.A.....	162, 172
Kliman, V.....	2063	Kristensson, G.....	1435
Klit, P.....	2443	Kross, D.A.....	329
Kloster, K.....	2033	Krothapalli, A.....	2259
Kluesener, M.F.....	1112	Kruger, W.E.....	1051
Knapp, A.E.....	559	Kruger, W.-D.....	978
Knauf, W.....	352	Krupka, R.M.....	529
Knepper, R.A.....	2253	Kruppa, P.....	1523
Knight, N.F., Jr.....	710	Kruse, B.J.....	602
Ko, Ching Long.....	1016	Krutul, J.....	786
Ko, Wen-Jiunn.....	2486	Krutzik, N.J.....	756, 757, 758
Kobayashi, A.S.....	213, 900	Krutzik, N.J.....	770, 876
Kobayashi, H.....	814	Ku, C.H.....	2286, 2547
Kobayashi, K.....	1450	Kubo, S.....	2089
Kobayashi, Y.....	849, 2229, 2529	Kubomura, K.....	1144
Koch, R.A.....	440	Kubota, Y.....	2466
Kocur, J.A.....	1745	Kucuk, N.C.....	1938
Koga, T.....	1407	Kucukay, F.....	2187
Koh, Aik-Siong.....	552	Kujath, M.....	2342
Kohgo, O.....	375	Kulak, R.F.....	299
Kohler, H.....	598	Kulp, C.R., Jr.....	216
Kohler, W.E.....	2036	Kumagai, Y.....	532, 2017
Kohno, T.....	357	Kumar, A.S.....	2344
Koide, T.....	1256, 1257, 1568	Kumar, Ch..R.....	1182, 1776
Koizumi, T.....	1676	Kung, L.F.....	1026, 2180, 2181

Lesuer, D.....	210	Liu, Y.N.....	110, 169
Lesueur, C.....	1055, 2392	Liu, Y.Z.....	25
Leung, A.Y.T.....	191, 2273	Livolant, M.....	806
Leung, K.H.....	964, 1184	Ljunggren, S.....	631, 1886
Leuridan, J.....	2312, 2517, 2546	Lo, H.R.....	2279
Leuridan, J.M.....	1600	Lobitz, D.W.....	1704
Leverenz, D.J.....	286	Lockau, J.....	860
Levine, M.B.....	285	Loeber, J.F.....	620
Levinge, R.W.....	1730	Loewenthal, S.H.....	1513
Levinson, M.....	128	Loh, Chin-Hsiung.....	878
Levran, J.....	1665	Loh, C.L.....	841
Lewicki, D.G.....	1033	Long, D.F.....	1456
Lewis, A.C.....	219	Longinotti, D.B.....	221
Li, Bin.....	2527	Longinow, A.....	288, 460, 1206
Li, Chang-Sheng.....	2406		1308
Li, Cheng De.....	2404, 2387	Loo, Yew-Chaye.....	1967
Li, Dabao.....	2602	Lopes, J.B.....	131
Li, D.....	1135	Lorch, D.L.....	315
Li, Jiansen.....	2342	Lotfi, V.....	1716
Li, P.....	414	Lottati, I.....	1220
Li, Tong.....	2404	Lou, Y.K.....	307
Li, Yue-feng.....	2364	Lowden, P.....	1836
Liang, C.G.....	1853	Lu, B.H.....	2547
Liang, Zhong.....	2395	Lu, I.T.....	111
Liao, S.....	151	Lu, L.K.H.....	368
Liauw, T.C.....	104	Lu, Qinnian.....	289
Libove, C.....	120	Lu, Shoudao.....	946
Librescu, L.....	1984	Lu, You-fang.....	2366
Liburdi, J.....	1836	Lubliner, E.....	1808
Liebler, M.E.....	1377	Lubrina, P.....	2411
Lieu, I.-W.....	2300	Lund, J.W.....	1869, 2443
Likins, G.E., Jr.....	903	Lundgren, T.S.....	1365
Lilley, T.....	223	Lundien, J.R.....	186
Lim, K.B.....	2571	Luo, Xiaoyu.....	2211
Lin, A.N.....	1335	Lupson, W.F.....	796
Lin, Hong-Tsung.....	1531	Lutes, L.D.....	1685, 1804
Lin, H.H.....	1951	Luu, T.P.....	143, 2479
Lin, J.....	1859	Luzzato, E.....	2267
Lin, J.I.....	637	Lynch, F.T.....	675
Lin, N.K.....	1721	Lynn, B.A.....	955
Lin, Shaoquan.....	2518	Lyon, R.H.....	1619, 2347
Lin, W.H.....	1291	Lysmer, J.....	770
Lin, Yaoqun.....	349		
Lin, Z.H.....	2547		
Lindberg, J.B.....	440		
Linde, M.....	2412		
Lindquist, M.R.....	1075, 1077		
Ling, F.H.....	2119		
Link, M.....	934, 935		
Linton, C.M.....	2240		
Lipkens, J.....	2517		
Lipvin-Schramm, S.....	461		
Little, C.D.....	1306, 1307		
Little, C.D., Jr.....	497		
Little, R.W.....	410		
Liu, G.Q.....	1594		
Liu, K.....	1641		
Liu, Man.....	2366, 2552		
Liu, S.C.....	761		
Liu, Y.....	1798		

- M -

Ma, Changshui.....	1519
Ma, C.C.....	2217
Ma, D.....	173
Ma, D.C.....	297, 557, 1998
	1199
Ma, Y.....	2514
Mabey, D.G.....	791
Macaskill, C.....	2513
Macavei, F.....	971, 977
MacBain, J.C.....	403, 1600
Mace, J.L.....	1801
Machin, A.S.....	796, 1221
Macioce, D.J.....	2561
Mackenzie, C.J.G.....	1548
Madden, R.....	1791, 2300

Kuno, T.....	1582	Lawrence, M.W.....	163
Kunquan, Zhu.....	1159	Lawrence, S.J.....	2488
Kuramitsu, M.....	931	Lawton, B.....	248
Kurdila, A.J.....	1327	Lawton, R.A.....	1484
Kuribayashi, Yutaka.....	1547	Lax, R.....	2523
Kurtz, R.J.....	505, 915	Leatherwood, J.D.....	798
Kurtze, G.....	1297	Lebrun, M.....	418, 514
Kurz, A.....	1908	Lecce, L.....	2154
Kurze, U.J.....	175, 1190	LeChatelier, C.....	2250
Kurzweil, L.G.....	894	Lecointre, C.....	2267
Kusama, H.....	638	Ledbetter, H.M.....	1108
Kuttruff, H.....	179	Lee, B.H.K.....	188, 267
Kvinge, T.....	2033	Lee, B.S.....	2150
Kwan, K.H.....	104	Lee, B.T.....	1110
Kwatny, H.G.....	886	Lee, C.K.....	307
Kyle-Little, J.....	53	Lee, C.W.....	534, 1694
- L -			
La Fontaine, R.F.....	148, 664, 861	Lee, F.H.....	2331
LaBouff, G.A.....	1251	Lee, G.F.....	1038
Lackney, J.....	1681	Lee, H.S.....	2132
LaFlamme, T.E.....	2449	Lee, Jang Moo.....	2384
LaFontaine, R.F.....	421	Lee, J.C.....	386
Lagnese, T.J.....	1035	Lee, J.H.....	174
LaGraff, J.E.....	1249	Lee, J.M.....	2132, 2234
LaGreca, P.D.....	1109	Lee, J.P.....	2499
Lai, D.C.....	1584	Lee, Moon Hee.....	479
Lai, Hsin-Yi.....	2389	Lee, M.C.....	2615
Lai, Shyh-Shiun.....	1390	Lee, Shaw-Cuang.....	881
Laithier, B.E.....	2479	Lee, S.H.....	1956
Lal, R.....	1282, 1436	Lee, S.J.....	949, 1876
Lalanne, M.....	274	Lee, S.L.....	1524
Lally, R.W.....	230, 2327	Lee, S.M.....	181
Lam, D.K.Y.....	398	Lee, S.W.....	49
Lambe, P.C.....	912	Lee, S.Y.....	2132
Lambert, R.G.....	2493	Lee, U.....	687, 1100
Lan, Nghiem-Phu.....	159, 164	Lee, You Yub.....	2281
Lan, Yuanhong.....	2189	Lee, Y.....	873
Langan, J.R.....	1063	Lee, Y.A.....	331
Lange, C.G.....	724, 725	Lees, A.W.....	383
Lange, Yu.V.....	1139	Lefebvre, D.....	200
Langley, R.S.....	558,	Lehmann, D.....	2590
Lapierre, H.....	2416	Lehmann, G.....	744
LaSala, K.J.....	2172	Leimbach, K.R.....	758
Lashkari, B.....	2239	226ipholz, H.H.E.....	2216
Lasota, H.....	435	Leissa, A.W.....	403, 1049, 1600
Laspesa, F.S.....	330 2232	
Lau, S.L.....	614, 615	Leister, P.....	782
Lauffer, J.P.....	2124, 2228	Lekoudis, S.G.....	2251
Laura, P.A.....	2467	LeMaster, R.L.....	253, 916
Laura, P.A.A.....	397, 847, 1052	Lembregts, F.....	2312, 2517
.....	1057, 1427, 1433 2546, 2551	
.....	1498, 1552, 1595	Lemieux, P.....	728
.....	1598, 1858, 1995	Lemire, G.R.....	447
.....	2459, 2467, 2469	Leon, R.L.....	250
.....	2473	Leonard, F.....	2319, 2341
Lavigne, P.....	2287	Leonard, J.W.....	522, 1720, 1757
Lawrence, C.....	1930	Lepicovsky, J.....	569
Lawrence, F.V., Jr.....	81	Lepik, U.....	376
		Lepore, F.P.....	27, 2383
		Lepschy, A.....	927
		Leroy, Y.....	200

Maddocks, J.H.	1964	Massoud, M.	2524
Madigosky, W	1128	Massouras, G.	2186
Maekawa, I.	481	Mastata, V.I.	979
Maekawa, Z.	433	Mastorakos, J.	1069
Mahan, J.R.	40, 1544	Masuda, T.	1567
Mahin, S.A.	236, 712, 764 1859, 2110	Masuko, Masami	1170, 1518, 1875
Maine, R.E.	524	Masumoto, Hiroki	1188, 1189
Maison, B.F.	546	Maszynska, A.	1342
Majewski, T.	1950	Matheva, T.	2264
Majima, O.	1274	Matkowsky, B.J.	680
Major, C.S.	1104	Matscholl, P.	1817
Majumdar, B.C.	1941	Matsuda, Satoshi	1267
Makovicka, D.	970	Matsuhisa, H.	747
Malahy, R.C.	1392	Matsui, Y.	1765
Malcolm, G.N.	792	Matsuishi, M.	1723
Malik, M.	1947	Matsumoto, H.	1639, 2004
Malik, S.N.	2023	Matsumoto, S.	1407
Mallik, A.K.	1421	Matsunaga, T.	282
Malthan, J.A.	152	Matsushita, Mikio	1772
Malvern, L.E.	122	Matsuuchi, Kazuo	1267
Mammola, C.G.	102	Matteucci, M.	452
Manderscheid, J.M.	355	Matysiak, S.J.	2066
Mann, J.Y.	796, 1221	Matzen, V.C.	255
Mannion, L.F.	1048	May, R.A.	2082
Manolis, G.D.	1239, 1377	Mayes, M.J.	1787
Manos, G.C.	139	Mayes, R.L.	1340, 2430
Mansour, A.E.	788	Mayes, W.H.	1215
Manu, C.	1682	Maymon, G.	190
Mar, J.W.	1099	Maynard, J.D.	873
Maragakis, E.A.	2141	Mayne, R.W.	2254, 2255
March, J.K.	362	Mazziotti, P.J.	4
March, P.A.	2240	Mazzoni, A.	2158
March-Leuba, J.	779, 2145, 2146	McCammon, D.F.	430
Margolis, D.L.	516, 1070	McConnell, K.G.	100, 198, 199
Marin, P.	976	McConnell, K.G.	1812
Mark, W.D.	597	McCormick, M.A.	1911
Marks, C.H.	99	McCoy, D.B.	2159
Markus, S.	382, 2003	McCroskey, W.J.	1743
Marlow, I.	1928	McCullough, M.K.	2104, 2174
Martireanu, Gh.	967	McDevitt, J.B.	678
Marshall, A.	2485	McFadden, P.D.	244, 600, 1138 1494, 1953
Marsteller, J.W.	795	McGrath, M.T.	56
Martens, M.J.M.	443	McGuckin, W.J.	252
Martin, H.R.	2338, 2343	McHugh, J.D.	943
Martin, J.B.	105, 1638	McKay, J.T.	1698, 2185
Martin, M.R.	502	McKenna, H.E.	340
Martin, V.	2483	McKenna, J.	1268
Martinez, D.R.	486, 1828, 2228	McKillip, R.M., Jr.	363
Martinovic, Z.N.	228	McKinnon, R.A.	2578
Marukawa, T.	1254	McLean, L.J.	196
Marulo, F.	2154	McVay, M.	769
Maskey, B.	393	Mead, D.J.	382, 1419, 1991
Maslov, L.I.	1811	Mechel, F.P.	2260
Maslowstet, A.	786	Meckl, P.H.	681
Mason, P.J.	1946	Mediratta, S.R.	202
Masopurt, R.	980	Medury, Y.	1393
Masti, S.F.	152, 937	Medwin, H.	1790
Massey, I.C.	1703	Meeks, C.R.	74, 75
Massmann, H.	2192	Meerkov, S.M.	1807

Mehl, J.B.	156	Miura, H.	1356
Mehta, N.P.	231, 1396, 1939	Miura, R.M.	724, 725
Mei, Chuh	1415, 1771	Mixson, J.S.	1541
Mei, C.	127, 1046	Miyachi, T.	1934
Mei, C.C.	1202	Miyachika, K.	1256, 1257, 1568
Meier, G.E.A.	1613	Miyagawa, Hiroomi	1324
Meijer, J.J.	1731	Miyao, K.	481
Meijer, S.	2412	Miyashita, Y.	372
Meirovitch, L.	691, 936, 1004	Miyazaki, M.	2526
Melcher, K.J.	945	Miyazaki, N.	2012, 2013
Mellor, M.	2504	Miyazono, S.	2012
Mendes Maia, N.M.	2362	Mizune, M.	1256
Menglin, Lou	1902	Mizuno, Eiji	1050
Menq, Chia-Hsiang	1245	Mizuno, K.	1621
Menq, C.-H.	1557, 2060, 2284 2285	Mizuno, M.	1582, 1864
Mercer, C.D.	105	Mizusawa, T.	1778, 2222
Merkle, D.H.	1899, 1900	Moe, G.	2237
Merritt, P.H.	518	Moehle, J.P.	840, 1379, 1710
Merritt, R.G.	2583, 2589	Moes, H.	72, 1250
Mertens, M.	2354	Mohammadi, J.	288, 460, 1308
Metz, K.L.	2426	Mohrle, W.	1817
Metwalli, S.M.	2175	Mohsiul, A.	1870
Metwally, H.M.	2378	Moitinho de Almeid, J.P.B.	623
Meyer, P.	1252	Molent, L.	1729
Meyer, R.A.	233	Molnar, A.J.	750
Meyers, G.E.	1309	Molusis, J.A.	1732
Miao, G.P.	25	Monaco, R.	879
Michaels, J.E.	1672	Monk, P.	1303, 2031
Michalopoulos, A.P.	806	Montalvao e Silva, J.M.	2362
Michalopoulos, D.	1749	Montgomery, R.C.	1003, 1326
Michaltsos, G.	2210	Moodie, T.B.	145, 854
Michon, J.C.	2117	Mook, D.T.	864, 1471, 2353 2486
Mickens, R.E.	2100	Mookerjee, P.	1732
Mikasinovic, M.	419	Moore, F.K.	1508
Miksad, R.W.	33	Moore, G.B.	187
Miles, J.W.	138, 645	Moore, T.	2388
Miles, R.N.	1000, 1655	Moore, T.N.	1369
Millarke, P.R.	2427	Morel, J.	2169
Miller, A.K.	1828	Morishita, E.	1701, 1702
Miller, D.F.	51	Morrisette, J.C.	2032
Miller, D.S.	44	Morita, Nobuyoshi	1258
Miller, G.F.	1213	Morris, P.J.	180, 571
Miller, J.D.	671	Morton, D.W.	2541
Miller, R.H.	359	Moser, M.	2016
Miller, R.K.	404, 720	Moses, F.	544
Miller, V.R.	313, 1002	Mosquera, J.M.	1271, 1640
Millot, P.	2392	Mostaghel, N.	2109
Mimovich, M.	2606	Mote, C.D., Jr.	88, 596, 2440 2610
Minca, I.	965, 969	Mottershear, J.E.	2282
Mines, R.A.W.	498	Mottier, F.M.	2078
Min-hua, Zheng	1302	Mouch, T.A.	2536
Mioduchowski, A.	533, 2310	Mountain, R.D.	867
Mirza, S.	1283	Mourelatos, Z.P.	1400
Mischke, J.	782	Mourjopoulos, J.	669
Misra, M.S.	1109	Mouroutsos, S.G.	523
Mitchell, L.D.	605, 905, 1862	Mu, Ting-tong	132
Mitchell, P.J.	722	Muckenthaler, T.V.	325
Mitchell-Dignan, M.	2280		
Mitropolsky, Yu.A.	923		

Mueller, K.....	1297	Nakazumi, A.....	950
Mukherjee, A.....	515, 928, 1501	Nakra, B.C.....	392
Mukherjee, K.....	646	Nalini, V.N.....	773
Mukhopadhyay, M.....	2219	Namachchivaya, N.S.....	2238
Muki, R.....	1441, 1896	Namba, M.....	1450
Mulcahy, T.M.....	2247	Nandlall, D.....	1466
Muller, G.....	860	Napadensky, H.....	1206
Muller, R.....	816	Napadensky, H.S.....	460, 1308
Muramoto, Y.....	1442	Narayanan, V.....	2391
Murata, M.....	482	Narita, Y.....	113, 1060, 1064
Murin, J.....	1959	2473	
Murkami, Yasunori.....	1157	Naruoka, M.....	126
Murphy, C.E.....	255	Naruse, J.....	154
Murphy, M.W.....	2199	Narvaez, G.....	1119
Murri, W.J.....	1123	Nasser, A.....	2170, 2314, 2435
Murty, A.S.R.....	2385	Nastasa, G.....	1025
Murty, A.V..Krishna.....	612	Nataraj, C.....	1863
Muscelino, G.....	1088	Nath, Y.....	851, 1065
Musson, B.G.....	2534	Natke, H.G.....	933, 941, 1023
Muszynska, A.....	895, 2379	1490, 2305, 2358	
Muthuswamy, V.P.....	838	Natsuaki, Y.....	126
Muthuveerappan, G.....	402	Nava, L.C.....	1427
Muto, T.....	1293	Navidi, P.K.....	2293
Myillyla, R.A.....	218	Nayak, A.P.....	2057
		Nayfeh, A.H.....	1147, 1346, 1966
		2275	

- N -

Naaman, A.E.....	618	Nedwell, J.....	2034
Nadolski, W.....	533	Neishlos, H.....	450
Nagabhushan, B.L.....	1230	Nelson, C.C.....	84, 2453
Nagabhushana, G.R.....	604	Nelson, C.E.....	2452
Nagai, K.....	2471	Nelson, H.D.....	539, 1863, 1867
Nagai, T.....	768	Neriya, S.V.....	369
Nagamatsu, A.....	1692, 2074	Neto, E.L.....	1999
Nagamatsu, H.T.....	1090	Neuss, C.F.....	546
Nagaraja, K.S.....	43	Neuwerth, G.....	816
Nagata, H.....	1647	Newman, D.L.....	145
Nagaya, K.....	106, 380, 532	Newman, J.S.....	337
	1052, 1052, 1276	Newnham, J.....	1957
	2177, 2471	Nezu, K.....	1639
Nagy, P.B.....	1787	Ng, D.S.....	2067
Nair, R.S.....	1983	Ng, K.O.....	74
Naitoh, M.....	1641	Ng, S.S.F.....	398, 2220
Nakagiri, S.....	18	Nicholas, J.C.....	1937, 2371
Nakahira, N.....	126	Nicholls, C.....	2091
Nakai, E.....	50	Nicholson, J.W.....	1312, 1416
Nakai, Mikio.....	1300	1425, 1468	
Nakai, M.....	371	Nicks, C.....	2452, 2453
Nakai, S.....	1712, 1713	Nicolas, J.....	447
Nakamichi, J.....	46	Niedbal, N.....	1830, 2160
Nakamoto, R.T.....	763	Nich, C.D.....	2246
Nakamura, A.....	2474	Nigm, M.M.....	390
Nakamura, K.....	445	Nikolaidis, E.....	1363
Nakamura, T.....	759, 1701, 1702	Nilakantan, G.R.....	942
Nakamura, Y.....	282	Nilsson, N.A.....	7, 10
Nakao, T.....	2114	Nishida, M.....	2484
Nakasako, N.....	445	Nishida, Shin-ichi.....	1188, 1189
Nakata, Y.....	2177	Nishimoto, T.S.....	1006
Nakayama, I.....	2474	Nishiwaki, H.....	1560
		Nisitani, Hironobu.....	1324
		Nissim, E.....	1031

Nitescu, G.....	277	Ono, K.....	500
Nixon, D.....	1798	Ookuma, M.....	1692, 2074
Njock Libii, J.....	2458	Oonishi, Masataka.....	1507
No, M.....	787	Opschoor, G.....	1310
Noel-Leroux, J.-P.....	806	Orthwein, W.C.....	1746
Nogami, T.....	19, 21, 1044	Ortiz, K.....	698
Noguchi, T.....	45, 1374	Ory, H.....	2415
Nulte, K.G.....	193	Osaki, S.....	433
Nonami, K.....	1506, 2445	Osorio R., J.A.....	729
Noori, M.N.....	892	Ostachowicz, W.....	1762
Nordmann, R.....	2192, 2244	Ostendarp, H.....	6
Norman, T.....	358	Ostrovska, G.....	2593
Norris, A.N.....	93, 172	Oswald, B.....	1358
Norris, M.A.....	1004	Ota, Hiroshi.....	1163, 1864
Norton, M.P.....	2020	Ottens, H.H.....	1914
Noutry, J.....	2490	Ousset, Y.....	1792
Novak, S.....	261	Out, J.M.M.....	1036
Nowinski, J.L.....	1606	Overvik, T.....	2237
Nozawa, N.....	2461	Ovunc, B.A.....	560, 1278
Nurhadi, I.....	1401	Owen, D.R.J.....	1594
Nyman, W.E.....	544	Oyadiji, S.O.....	1078, 1079

- O -

Ochoa, O.O.....	632
Oda, S.....	1256, 1256, 1257
Officer, C.B.....	1568
Ogawa, K.....	157
Oh, B.H.....	2092
Oh, Jae Eung.....	1658
Oh, Jae Eung.....	1517, 2281, 2460
Oh, K.P.....	71
Ohanchi, D.C.....	605
Ohayon, R.....	2022
Ohkami, Y.....	50
Ohkawara, K.....	532
Ohlrich, M.....	2274
Ohlsson, S.....	583, 2137
Ohmata, K.....	2058
Ohno, K.....	2462
Ohta, H.....	154
Ohta, M.....	445, 1628
Ojalvo, I.U.....	2324
Okada, I.....	1589
Okada, Y.....	346, 466
Okamura, Haruo.....	1758
Okigami, T.....	2500
Okrouhlík, M.....	2198
Okubo, N.....	2526
Okumura, K.....	922
Okuno, A.F.....	678
Olausson, H.L.....	2125
Oldfield, M.L.G.....	1244
Oliver, D.E.....	2521
Olsen, J.J.....	531
Olsen, N.L.....	2520
Olsson, M.....	2457
Olsson, P.....	1301
Om, D.....	660
On, F.J.....	2419

- P -

Pacejka, H.B.....	284, 301
Padovan, J.....	924, 1681
Paez, T.L.....	1805, 2051, 2600
Page, D.B.....	1337, 2577
Paidoussis, M.P.....	143, 2011, 2479
Paipetis, S.A.....	347, 2055
Pak, Chan-Gi.....	2384
Pak, R.Y.S.....	1384
Pal, T.....	1825
Palamas, J.....	14
Paliwal, D.N.....	1605
Palluzzi, V.H.....	1598
Palmatier, G.E.....	1342
Palylyk, R.A.....	2199
Pan, H.H.....	2302
Panagiotopoulos, P.D.....	1577
Panayotounakos, D.E.....	607
Pandit, M.....	1486
Pandit, S.M.....	231, 2306
Panesar, A.....	1288
Panossian, H.V.....	2162
Pao, Y.-H.....	1672
Papa, L.....	2475
Papadopoulos, D.P.....	2027
Papadarakis, M.....	622
Papanicolaou, G.....	444, 2101

Papastavridis, J.G.	1470	Pfeiffer, F.	2187
Papoulias, F.A.	1540	Phan, N.D.	114
Pappalardo, M.	452	Piaggio, R.	2158
Pardoen, G.C.	2224, 2280, 2425	Pickering, C.J.D.	2328
Pardue, E.F.	2341	Pielorz, A.	533
Pariseanu, G.	837	Pierre, C.	1054
Park, Jun Chul	2460	Piersol, A.G.	2401
Park, T.W.	2356	Piety, K.R.	2341
Park, Young-Ji	547, 960, 961	Pih, H.	1124
Park, Y.P.	88	Pike, J.	599
Parker, R.	8, 1488	Pilkey, W.D.	303, 466, 1636 2094
Parnes, R.	925	Pillot, C.	468
Parrott, T.L.	1786	Pinkus, O.	1565
Parthasarathy, G.	636, 1996	Pinnington, R.J.	2225
Pastor, M.	964, 1184	Pinsky, M.A.	2102
Patamapongs, N.	256	Piombo, B.	2481
Patel, M.H.	743, 2400	Piotrowski, J.	1364
Patil, S.P.	555	Pires, J.	1719
Patrick, G.B.	2320	Pisarenko, G.S.	1927
Patrikalakis, N.M.	97, 1588	Pistek, V.	1551
Patt, J.	210	Pister, K.S.	842, 2110
Patz, G.	1311	Pitimashvili, I.A.	2045
Paul, D.B.	1771	Pitman, K.E.	260
Paul, H.S.	194	Piziali, R.L.	2204
Paule, D.W.	2555	Pizzamiglio, M.	2158
Paulson, S.K.	21	Planat, M.	1642
Paunescu, M.	973	Planchard, J.	652, 781
Pavese, M.	2481	Plante, R.L.	58
Pavic, G.	704, 705	Plaut, R.H.	626, 864, 1592 2353, 2486
Pavlin, V.	503	Plesha, M.E.	1686
Payne, R.C.	1213	Plint, A.G.	1092
Pazargadi, S.	2235	Plint, M.A.	1092
Pazsit, I.	918	Plunkett, R.	86, 1412
Pearson, D.	1556, 1739	Poinsot, T.	2250
Pearson, L.H.	1341	Poland, J.B.	2327
Pech, W.	1667	Polidor, B.	1103
Pecknold, D.A.	1528	Polizzotto, C.	1660
Pedersen, P.	1978	Poltorak, K.	1276, 1426
Pedersen, P. Ternd	789	Pombo, J.L.	1552
Pedersen, P.C.	870	Pook, L.P.	701
Peek, R.	1080	Poole, L.A.	423
Peeken, H.	1569	Pope, L.D.	999
Pekau, O.A.	16, 958	Popinceanu, N.G.	899
Peleg, K.	1926	Popov, E.P.	764
Pell, R.A.	1221	Popplewell, N.	2256, 2519
Pellegrino, E.	2402	Popson, M.J.	13
Peng, Zemin	2298	Porat, I.	944
Penland, C.	868	Porter, M.B.	176
Perez, R.B.	2145, 2146	Poterasu, V.F.	805
Perkins, J.	2332	Potesil, A.	1795
Perkins, N.C.	2610	Pototzky, A.S.	1727
Perrin, R.	649	Powell, C.A.	336, 999, 2035
Perry, B.	42	Powell, C.D.	13
Perry, B., III	1727	Power, J.	640, 641, 643
Perz, P.	1483	Powers, E.J.	33
Pesce, C.P.	2148	Powers, J.	1789
Petrick, L.J.	1705	Prabhu, B.S.	1943, 1944
Petrovich, A.	215, 1545	Prabhu, M.S.S.	328
Pettigrew, M.J.	1069		
Pezeshki, C.	1764		

Prakash, B.G.	328
Pramono, E.	957
Prasad, M.G.	432
Prashad, H.	1496
Prater, G., Jr.	1475
Prathap, G.	2205
Prats, D.J.	1737
Preumont, A.	462
Prevost, J.H.	775, 984
Price, S.J.	2011
Price, S.M.	2127, 2549
Price, W.G.	91, 2059
Prikyrly, K.	214
Pritz, T.	2168
Privitzer, E.	343
Prosser, W.H.	234
Providakis, C.P.	1763
Provo Kluit, J.C.	206
Prucz, J.	820
Prucz, J.C.	1404
Prucz, Z.	62
Prydz, R.A.	39
Pumplin, J.	226
Purasinghe, R.	741
Pust, L.	1849
Putcha, N.S.	1428
Ramaswamy, V.	202
Ramulu, M.	900
Rand, O.	374, 1740
Rand, R.H.	734
Randolph, M.F.	20, 1901
Rao, B.M.	393
Rao, B.V.A.	448
Rao, D.K.	476, 2559
Rao, J.S.	1160, 2372
Rao, K.V.	1627
Rao, S. Nagaraja	633
Rao, S.N.	1775
Rao, S.S.	579, 1857
Rapacki, G.R.	1102
Raptis, A.C.	1291
Rashed, A.A.	771
Rashidi, M.	593
Rasmussen, E.A.	993
Rasmussen, G.	2540
Raspet, R.	1623
Rastogi, P.K.	1497
Rathe, E.J.	171
Rausche, F.	903
Rautenberg, M.	1509
Ravindra, M.K.	29
Razzaq, Z.	1767

- 9 -

Qamaruddin, M.	1522
Qian, Z.W.	1452
Qiou, Yang	2211
Qiu, Xiangjun	2183
Qu, J.	2202
Quan-Sheng, Xie	1209
Quck, S.T.	1524
Quinn, R.D.	1004
Qun-Chao, Zhu	1209

- R -

Radcliffe, C.J.....	489
Rades, M.....	711, 2075
Radon, J.C.....	1115
Radziminski, J.B.....	370
Ragab, A.....	1200
Raghavan, T.....	838
Rahman, M.....	751, 2134, 2391
Rahman, Z.....	2099
Rahnejat, H.....	594
Rainer, J.H.....	2079
Raisinghani, S.C.....	2153
Rajalingham, C.....	1943, 1944
Rajamani, A.....	2207
Rajan, M.....	1867
Rakheja, S.....	683, 732, 2405
Rama Rao, P.....	202
Ramachandran, J.....	1285
Ramaiyan, G.....	399
Ramakrishna, D.S.....	2152

Ramaswamy, V.	202
Ramulu, M.	900
Rand, O.	374, 1740
Rand, R.H.	734
Randolph, M.F.	20, 1901
Rao, B.M.	393
Rao, B.V.A.	448
Rao, D.K.	476, 2559
Rao, J.S.	1160, 2372
Rao, K.V.	1627
Rao, S. Nagaraja	633
Rao, S.N.	1775
Rao, S.S.	579, 1857
Rapacki, G.R.	1102
Raptis, A.C.	1291
Rashed, A.A.	771
Rashidi, M.	593
Rasmussen, E.A.	993
Rasmussen, G.	2540
Raspet, R.	1623
Rastogi, P.K.	1497
Rathe, E.J.	171
Rausche, F.	903
Rautenberg, M.	1509
Ravindra, M.K.	29
Razzaq, Z.	1767
Reason, J.	504
Rebello, C.J.	1777
Rechard, R.P.	1340
Reddy, A.	820
Reddy, A.S.S.R.	1132
Reddy, C.V.R.	636, 1996
Reddy, E.S.	650, 1421, 1446
Reddy, J.N.	114, 1428
Reddy, V.R.	2130, 2390
Reed, A.T.	1913
Rees, I.G.	177
Reese, R.T.	2082
Rega, G.	2454
Regan, R.	598
Rehak, M.L.	1207
Rehfield, L.	820
Rehfield, L.W.	190
Reibold, R.	428, 2538
Reich, M.	1719, 2398
Reid, R.E.	1495
Reif, Z.	2388
Reinberg, E.	47
Reinhall, P.G.	1655
Reinhorn, A.	62
Reinhorn, A.M.	1239
Reinig, K.D.	1738
Reiss, E.L.	162, 172, 176 513, 1843
Reiss, R.	2346
Remillard, R.L.	919
Remington, P.J.	1204
Remmerswaal, J.A.M.	284
Remseth, S.	1906
Ren, L.X.	621

Renganathan, K.....	194	Rosenberg, R.M.....	887
Renkey, E.J.....	1075	Rosenhouse, G.....	1083, 1616, 1992
Rentz, R.R.....	117	Rosenkilde, C.E.....	877
Rentz, T.R.....	401	Ross, C.A.....	122
Revell, J.D.....	39	Ross, T.J.....	613
Reyer, K.....	716	Rossi, G.A.....	1988
Reznicek, M.E.....	238	Rossi, S.M.....	2574, 2575
Rhode, D.L.....	1754	Rossing, T.....	649
Riaz, B.....	1459	Rost, R.W.....	2076
Ribner, H.S.....	1082	Rotert, D.....	933
Rice, E.J.....	1299	Roure, A.....	1081
Rice, J.M.....	520	Rousselet, J.....	144
Rice, R.B.....	1102	Rousselet, J.L.....	1601
Rich, R.B.....	1101	Roy, A.K.....	86, 1412
Richards, E.J.....	541, 1174, 1354	Roy, F.....	703
	1455, 1474, 2263	Roy, R.H.....	1229
	2510	Roy, R.P.....	986
Richards, T.L.....	434	Rubin, C.A.....	902
Richardson, M.H.....	2308	Rubin, M.B.....	1650
Ricketts, R.H.....	317	Rubin, S.....	1675
Riddell, R.A.....	556	Rubio, P.....	1350
Rieger, N.F.....	351, 1030, 1670	Rudd, J.L.....	1121
	2090	Rudd, M.J.....	1819
Riggs, H.R.....	765	Rudder, F.F.....	425
Rihal, S.S.....	2025	Ruhlin, C.L.....	43
Ringermacher, H.I.....	720	Ruiz, C.....	498
Risitano, A.....	606	Russell, D.L.....	739
Rivin, E.I.....	862, 1553, 1571	Russell, L.T.....	1084
Roach, D.P.....	2598	Russell, S.S.....	235
Roberson, R.E.....	1145	Rutenberg, A.....	23
Roberts, J.B.....	34, 35, 1946	Ryan, J.E.....	2172
	2050	Ryan, R.J.....	1542
Roberts, J.W.....	1414	Ryland, G.....	691
Robertson, D.K.....	1761		
Robinson, R.R.....	288, 1206		
Roblee, J.W.....	1397		
Roblyer, S.P.....	920		
Rocha, S.M.....	1343		
Rocklin, G.T.....	2317		
Rockwood, W.B.....	368		
Rodeman, R.....	2325		
Rodriguez, O.....	880		
Roeder, C.W.....	829		
Roesems, D.....	1543		
Roessett, J.M.....	939		
Roger, M.....	1612		
Rogers, J.C.....	181		
Rogers, J.D.....	198, 199		
Rogers, L.....	1148, 1149		
Rogers, L.C.....	470		
Rogers, R.J.....	1351		
Roget, J.....	207		
Rohlf, D.....	576		
Rollwage, M.....	1305		
Rorres, C.....	870		
Rosati, V.J.....	220		
Rosch, D.....	2086		
Rosen, A.....	374, 592, 1740		
Rosen, I.G.....	384		
Rosenberg, R.....	929		

- S -

Saberi, H.A.....	1229
Sabol, T.A.....	1375
Sabuncu, M.....	1032
Sackman, J.L.....	185
Sadek, E.A.....	103, 1272
Sadek, M.M.....	390, 1706
Sadler, G.G.....	945
Sahinkaya, M.N.....	1, 1938
Sahli, A.H.....	545
Saigal, S.....	133, 2179, 2476
Saiidi, M.....	2141
Saito, S.....	538
Saito, Takashi.....	1871
Saito, T.....	2122, 2477
Sakata, M.....	412
Sakawa, Y.....	950
Salikuddin, M.....	2248
Salman, F.K.....	2378
Samaha, M.....	1538
Samali, B.....	761, 956, 1865
Samanta, B.....	515, 928, 1501
Sambasiva Rao, M.....	328
Samejima, Makoto.....	1166
Samoilenko, A.M.....	923

Sampson, R.C.	249	Schmidtberg, R.	1825
Samp-Staniskawska, E. M.	388	Schmitt, J.	484
Samra, B.S.	1211	Schneider, D.	31
San Andres, L.	2053	Schneider, M.E.	1105
Sanchez Sarmiento, G.	1433, 1595	Schnobrich, W.C.	149
Sandberg, L.B.	901	Schober, K.	716
Sandford, M.C.	317	Schollhorn, H.-D.	863
Sandhu, R.S.	525	Schomer, P.	305
Sandi, H.	975	Schoof, C.C.	673
Sandler, I.S.	1207	Schramm, E.J.	252
Sandman, B.E.	467	Schroeder, E.A.	2047
Sandor, G.N.	1259	Schroeder, R.A.	530
Sankar, B.V.	182, 683, 732 1413, 1478, 2405	Schultz, D.L.	1249
Sankar, T.S.	369, 540, 1538 1940, 2344, 2373	Schulz, R.	1402
Sankaranarayanan, N.	399	Schuss, Z.	680
Santos, A.P.	1967	Schwartz, C.W.	271
Santos, R.D.	2469	Schwartz, H.W.	1909
Santu, I.Al.	979	Schwarz, J.	1618
Sarig, Y.	410	Schweikhard, W.G.	1834
Sarigul (Aydin), A. S.	1583	Schwer, M.	1652
Sas, P.	2311, 2566	Schwirian, R.E.	556
Sasaki, M.	381, 1280	Scibbe, H.W.	2446
Sathyamoorthy, M.	619, 634, 1735	Sclavounos, P.D.	36
Sato, H.	1968	Scruby, C.B.	246
Sato, K.	367, 2447	Seaman, L.	1123
Sato, O.	1255	Seaman, R.L.	1750
Sato, S.	747	Seering, W.P.	681
Sato, T.	1566, 2448	Segal, D.J.	56
Sato, Y.	843	Segerlind, J.J.	410
Sattar, M.A.	2056	Sehmi, N.S.	624
Sattary-Javid, V.	1972	Seiler, F.	1802
Sattleger, J.	1352	Seireg, A.	658
Savage, M.	1033	Sekiguchi, H.	1621, 1653
Savci, M.	2226	Sekiguchi, Masatoshi	1772
Sawada, Tatsuo	1313, 2014	Selerowicz, W.C.	1613
Sawan, J.	609	Sellers, C.D.	2147
Sawyer, J.W.	1034	Sen, P.K.	2569
Sayhi, N.	1792	Sen, R.	1385
Sazawal, V.K.	2023	Send, W.	364
Scanlan, R.H.	951, 952	Senda, T.	245
Scarano, G.	452	Serag, S.	2170, 2435
Schanzer, G.	793	Sergeev, V.I.	1958
Scharter, J.	2452	Sethna, P.R.	855
Scharter, J.K.	1961	Seto, K.	344, 345
Schein, D.B.	1786	Settgast, W.	1736
Schenke, N.	1014	Severn, R.T.	15
Schewe, G.	387	Severud, L.K.	1077
Schick, D.	155, 665, 666	Severyn, T.P.	313
Schiefferly, C.	1928	Shabana, A.	690
Schiess, J.R.	1644	Shabana, A.A.	742, 1329, 1457 1651, 2345
Schif', A.J.	893	Shah, A.H.	1447
Schiff, L.B.	790, 792, 998	Shahrivar, F.	2335
Schijve, J.	206	Shaked, M.	2593
Schirmer, P.J.	326	Shangchow, C.	2469
Schlagheck, J.G.	2492	Shankaran, R.	409
Schmidt, A.A.	329	Shanmugam, N.E.	112, 617
Schmidt, H.	1150, 1151, 1152 1153, 1154, 1155	Shao-ping, S.	2142
		Sharan, A.M.	501, 1160, 2130 2390

Sharan, S.K.	772, 1349, 2054	Singh, R.	1475
Sharma, A.M.	865, 1298	Singleton, N.R.	556
Shaw, L.M.	1563	Singnoi, W.N.	1834
Shaw, S.W.	87	Sinha, A.	1361, 1929
Sheen, R.L.	1010	Sinha, G.L.	2385
Shen, C.N.	874, 1499	Sinha, S.N.	1605
Shen, F.	469	Sinharay, G.C.	2000
Shen, Y.	1993	Sipcic, S.	48
Shen, Zong Han	629	Sivakumaran, K.S.	1056
Shepard, G.D.	2417, 2565, 2570	Skidmore, G.R.	689, 1477
Shepherd, I.C.	148, 421, 664	Skreiner, K.M.	2399
	861	Skrikerud, P.E.	1814
Shepherd, K.P.	2035	Sladek, J.	2098
Sherf, Z.	2408, 2587, 2593	Sladek, V.	2098
Sherick, C.E.	54	Slater, J.E.	394
Shestopal, V.O.	2472	Slawson, T.R.	459, 2041
Shiau, Ting-Nung B.	365	Slone, R.M., Jr.	2421
Shibahara, M.	1765	Smallwood, D.O.	2465, 2548, 2601
Shibusawa, Shigehiko	1845	Smigelski, P.	1325
Shick, D.V.	487	Smiley, R.G.	2320
Shiga, M.	353	Smith, B.S.	1708
Shije, S.	2142	Smith, B.V.	161
Shilin, Chen	1159	Smith, C.E.	66
Shilkrut, D.	463	Smith, C.S.	1615
Shimada, S.	1885	Smith, D.A.	2422
Shimoda, H.	2058	Smith, E.L.	1491
Shimojima, H.	1255	Smith, H.W.	216
Shin, C.S.	204	Smith, I.	1235
Shin, Y.S.	401	Smith, J.D.	244, 600, 1494
Shing, Pui-Shum B.	236, 712	Smith, K.S.	1087
Shinkle, G.A.	911	Smith, L.C.	1076
Shiozawa, K.	481	Smith, P.W.	1111
Shiu, K.N.	2026	Smith, P.W., Jr.	1630
Shizawa, Kazuyuki	2014	Smith, R.A.	82, 204
Shockey, D.A.	700	Smith, R.L.	2605
Shoenberger, R.W.	1015	Smith, S.	2573
Shoji, F.F.	926	Smythe, R.C.	1285
Shteyngart, S.	1294	Snoeys, R.	2311, 2354, 2566
Shulemovich, A.	1611	Snyder, V.W.	197, 906
Shye, K.Y.	2399	So, H.	1564
Siddharthan, R.	293	Soares, F.R.	1359, 2120
Sierakowski, R.L.	672	Soares, W.A.	298
Silas, G.	2073	Soares-Filho, W.	1629
Silas, G.H.	1243	Soebagio,	2381
Sill, R.D.	708	Soedel, W.	174, 1026, 1410
Simek, J.	1948		2179, 2180, 2181
Simkova, O.	2003	Sofue, Y.	1934
Simmonds, J.G.	1068	Sohaney, R.C.	2320
Simonen, F.A.	780	Sohn, J.L.	465
Simonian, S.S.	1104	Sol, H.	2464
Simons, H.A.	20, 1901	Solecki, R.	1444
Simpkins, P.G.	1268	Sone, A.	2006
Simulescu, I.	1502	Song, Jianwei	2298
Singer, J.	825, 1607	Song, J.	93
Singh, A.	1396, 1939	Song, T.-X.	2201, 2303
Singh, B.	396	Soni, S.R.	217
Singh, B.P.	413, 824	Soom, A.	1645, 2539
Singh, K.	413	Soong, T.T.	62
Singh, M.P.	865, 1298, 1520	Soovere, J.	1002, 1985
	1533	Sophianopoulos, D.	1981

Sorge, F.....	1755	Stoneman, S.A.T.....	8, 1488	
Sorocky, S.J.....	2416	Storti, D.W.....	1649	
Soucy, Y.....	728, 1826,	2363	Stout, R.B.....	1089
Souflis, C.....	2105	Strahle, W.C.....	2251	
Soule, S.....	2161	Straub, F.K.....	361	
Soundatarajan, A.....	735	Stromsta, R.....	2257	
Spanos, P.D.....	1804,	2050	Stroud, R.C.....	2163, 2591
Sparis, P.D.....	523	Sturm, A.....	242, 2086	
Spencer, B.F.....	2096	St. Balan, F.....	967	
Spencer, B.F., Jr.....	65, 890	St. Doltsinis, J.....	1908	
Spencer, D.B.....	254	St. John, C.M.....	1185	
Sperle, J.O.....	205	Su, Qing-Za.....	777	
Spiekermann, C.E.....	489	Suarez, S.A.....	1106	
Spieldener, J.P.....	207	Subbiah, R.....	540, 1940, 2373	
Spigler, R.....	1345	Subrahmanyam, K.B.....	12, 591, 1027	
Spivack, M.....	2513	Subudhi, M.....	1294, 2398	
Springer, W.T.....	237, 238	Sudo, Seiichi.....	1316, 1317	
Srinivasan, A.V.....	898, 1930,	Sudo, S.....	1443	
Srinivasan, G.R.....	2509	Sudou, K.....	2482	
Srinivasan, M.G.....	1743	Suematsu, H.....	2064, 2291	
Srinivasan, R.S.....	1196	Sueoka, Atsuo.....	1166, 1516, 1539	
Srirangarajan, H.R.....	405, 639	Sueoka, A.....	512, 2093	
Stachowiak, G.W.....	2463	Sues, R.H.....	29, 549	
Stadelbauer, D.G.....	2368	Sugeng, F.....	1562	
Stahl, B.....	1679	Sugg, F.E.....	232	
Stahle, C.V.....	559	Sugihara, M.....	232	
Staley, J.A.....	2463	Sugita, Hiroshi.....	1701, 1702	
Stalnaker, D.O.....	324, 1011	Sugiura, Kunitomo.....	1188, 1189	
Stancu, M.....	324, 1011	Sugiyama, Y.....	1163	
Stanway, R.....	211	Sullivan, P.A.....	1050	
Stanworth, C.G.....	1022	Sumida, M.....	657, 2017	
Starkey, J.M.....	584	Summa, J.M.....	564	
Starrh, L.I.....	1695	Sumner, J.B.....	2482	
Stastny, M.....	1462	Sun, C.T.....	1224	
Stathopoulos, T.....	1028	Sun, C.T.....	1916	
Statnikov, I.N.....	955	Sun, Fangning.....	182, 406, 1110	
Staudacher, K.....	1958	Sun, Fangning.....	1413, 1418, 2511	
Stavrindis, C.....	810	Sun, H.B.....	2387	
Steck, J.E.....	2164	Sun, H.B.....	1474, 2510	
Steele, J.M.....	1784	Sun, J.C.....	1354, 1474, 2263	
Steffen, V.....	913, 2441	Sun, J.C.....	2510	
Steffen, V., Jr.....	27	Sun, Jinghong.....	2133	
Stehle, C.D.....	2383	Sun, Wei-Joe.....	454	
Steinwender, F.....	1550	Sun, Yan-jun.....	201	
Stephen, N.G.....	2244	Sun, Yueming.....	2360	
Stephens, J.E.....	378	Sundarajan, N.....	1003, 1326	
Stevens, D.S.....	1383	Sundin, K.G.....	706	
Stevens, J.R.....	2077, 2329	Sung, C.K.....	751	
Stevens, K.....	2534	Surace, G.....	1751	
Stevens, K.K.....	1277	Sutantra, I.N.....	1434	
Stewart, R.M.....	131, 1505	Suzuki, K.....	302	
Stiefel, W.....	251	Suzuki, K.....	372, 458, 1289	
Stillman, D.W.....	78, 79	Suzuki, K.....	2006, 2232	
Stimpfing, A.....	988	Suzuki, S.....	1979	
Stimpson, G.J.....	1325	Suzuki, S.-I.....	2221	
Stirnemann, A.....	1174, 2263	Suzuki, T.....	2448	
Stoessel, J.C.....	171	Suzuyama, T.....	357	
Stokes, A.N.....	2426	Svoboda, R.....	1838	
Stone, B.J.....	1451	Swaddiwudhipong, S.....	1524	
Stone, V.M.....	2277	Swalley, J.C.....	1699	
	2582	Swansson, N.S.....	1344	
		Swinson, W.....	129	

Swinstra, S..... 1748
 Syamal, P.K..... 16, 958
 Symonds, P.S..... 1047, 1271, 1640
 Syvertsen, K..... 1906
 Szafir, D.R..... 818
 Szemplinska-Stupnicka, W..... 1467
 Szeri, A.Z..... 1949
 Szrom, D.B..... 1678
 Szumowski, A.P..... 1613
 Szwedowicz, D..... 1762
 Szymkowiak, E.A..... 2491, 2588

- T -

Ta, K.D..... 1351
 Tadakawa, T..... 50
 Tadjbakhsh, I.G..... 807, 823, 1018
 Taesiri, Y..... 769
 Tait, H.J..... 2609
 Tait, R.J..... 2108
 Takada, H..... 2462
 Takagami, T..... 1923
 Takahagi, Toshio..... 1300
 Takahashi, D..... 871, 1894, 1895
 Takahashi, K..... 1293
 Takahashi, M..... 635
 Takahashi, S..... 372, 1289
 Takamatsu, Y..... 2123
 Takase, F..... 931
 Takatsu, N..... 367, 2447
 Takatsubo, J..... 2029
 Takeda, H..... 926
 Takeda, K..... 1560
 Takeda, S..... 2177
 Takewaki, I..... 759
 Takita, Y..... 344
 Tallin, A..... 755, 1378
 Tallin, A.G..... 290
 Talmadge, R.D..... 1338
 Tam, C.K.W..... 571
 Tamura, Akiyoshi..... 1507
 Tamura, A..... 76, 1809
 Tamura, Hideyuki.... 1166, 1516, 1539
 Tamura, H..... 366, 512, 2093
 Tamura, T..... 1713
 Tan, Ming-yi..... 2562
 Tan, S.A..... 1386
 Tanahashi, Takahiko.... 1313, 2014
 Tanaka, Hideo..... 1246, 1247, 1248
 Tanaka, Nobuo..... 1879
 Tanaka, N..... 63, 282, 588
 2433, 2434
 Tanaka, Y..... 657
 Tang, D.M..... 1559
 Tang, D.T..... 1135
 Tang, Renzhong..... 2360
 Tang, Xiujin..... 1171, 2309
 Tang, Y..... 2005
 Tani, J..... 1443
 Taniguchi, R..... 1676

Taniguchi, S..... 1653
 Tanna, H.K..... 180, 567
 Tappett, F..... 159, 164
 Tarter, J.H..... 1909
 Tassoulas, J.L..... 1531
 Tatimir, S..... 981
 Tauriainen, D.G..... 60
 Tayel, M.A..... 852
 Taylor, D.L..... 1706, 1945
 Taylor, H.M., Jr..... 2041
 Taylor, J.L..... 1674
 Taylor, R.L..... 1898
 Taylor, T.T..... 780
 Tee, L.B..... 253, 916
 Teixeira de Freitas, J.A..... 623
 Tellbuscher, E..... 1873
 Teodoro, E.B..... 2383
 Tesar, A..... 647, 2227
 Tezuka, Atsushi..... 1518
 Thaller, R.E..... 2420
 Tham, L.C..... 1773
 Thambiratnam, D.P.. 1183, 1965, 2194
 Theissen, J..... 6
 Thiede, R..... 941, 1023
 Thinnis, G.L..... 2242, 2478
 Thiruvengadam, V..... 153
 Thiruvenkatachari, V..... 405, 639
 Thoma, J.U..... 2365
 Thomas, A.G..... 809
 Thomas, D.L..... 383
 Thomas, H.-M..... 1140
 Thomas, M..... 2524
 Thomas, P..... 2169
 Thomas, R.S.D..... 116
 Thompson, A.R..... 1791
 Thompson, B.S..... 1751
 Thompson, D.O..... 1339
 Thompson, R.A..... 1877, 1878
 Thompson, R.B..... 1339
 Thornhill, L..... 2019
 Thrane, H.W..... 723
 Thuestad, T..... 1906
 Thummel, J..... 155, 665, 666
 Tichy, J..... 423
 Tichy, J.A..... 1398
 Tier, C..... 680
 Tiernego, M.J.L..... 519, 932
 Tiersten, H.F..... 1285, 2077, 2329
 Tilly, G.P..... 212
 Tindle, C.T..... 869
 Tischler, V.A..... 1091
 Tjong, Jimi Sauw-Yoeng..... 2388
 Tlusty, J..... 1874
 To, C.W.S..... 1072, 2357
 Tobak, M..... 316
 Tobler, R.L..... 1116
 Tobler, W.E..... 283
 Todo, I..... 1290
 Toffer, H..... 920
 Tohyama, M..... 2498

Tokuhashi, H.....	1809	Tunna, J.M.....	699
Toledo, E.M.....	1067	Turczyn, M.T.....	1724
Tomar, J.S.....	125	Turek, F.....	1838
Tominaga, T.....	2557	Turner, J.....	129
Tomita, K.....	521	Turnock, D.L.....	527
Tomita, Y.....	1979	Tustin, W.....	715, 910, 1818
Tomlinson, G.R.....	1078, 1079, 2531	Tyagi, D.K.....	396
Tondl, A.....	896, 1697	Tzavelis, C.A.....	389
Tong, Zhongfang.....	2360	Tzou, H.S.....	893
Tongue, B.H.....	1225	 - U -	
Torby, B.J.....	2125	Uddin, W.....	554
Torii, T.....	1574, 1963	Udwadia, F.E.....	550
Torkamani, M.A.M.....	957, 1521	Ueda, Shuzo.....	858
Torngren, L.....	1912	Ueda, S.....	2013
Toro, G.R.....	1847	Uhl, T.....	1856
Torvik, P.J.....	471	Uhlemann, S.....	242, 2086
Toshimitsu, K.....	18	Ujihashi, S.....	2004
Totani, T.....	1506	Ukrainetz, P.R.....	2195
Touratier, M.....	2190	Ulbrich, H.....	537
Townley, G.E.....	2289	Ulm, S.C.....	2560
Townsend, D.P.....	2446	Ulríksson, B.....	1485
Tozzi, J.T.....	1608	Ulsoy, A.G.....	1881
Trachsler, T.....	2539	Umaretiya, J.R.....	1431
Trethewey, M.W.....	2323	Umezawa, K.....	1566, 1954, 2448
Tretiak, O.J.....	870	Ungar, E.E.....	894
Triantafyllidis, T.....	1893	Unlusoy, Y.S.....	2178
Triantafyllou, M.S.....	1261, 1411	Urashima, Chikayuki.....	1188, 1189
Trochides, A.....	391, 444, 1273	Uscinski, B.J.....	2513
	2261	Utjes, J.C.....	1595, 1598
Troeder, C.....	1569	Utsumi, M.....	412
Trogdon, S.A.....	115	Uzuner, B.....	1118
Tromp, J.H.....	1069	 - V -	
Trossbach, R.....	1638	Vaicaitis, R.....	109, 573, 1214
Trubert, M.....	323	Vaicaitis, R.....	2156, 2165, 2410
Trudell, R.W.....	820	Vaidya, P.G.....	659
Trum, A.....	1201	Vail, J.A.....	1816
Truman, K.Z.....	1373, 1889	Vakakis, A.F.....	347, 1237, 2055
Trummer, D.....	2506	Valdy, N.R.....	2429
Trundle, C.C.....	2166	Valero, N.A.....	1932
Tsai, Pwu.....	510	Valsgard, S.....	563
Tsai, T.....	503	Van Campen, D.H.....	1021
Tsakonas, S.....	422	Van de Ponseele, P.....	2566
Tsang, S.H.L.....	1071	Van der Auweraer, H.....	2311, 2354
Tsangaris, S.....	857		2517, 2546
Tseng, K.....	48	van der Heijden, L.A.M.....	443
Tseng, W.S.....	804	van der Linden, H.H.....	1955
Tso, W.K.....	1197, 1634, 1888	van der Merwe, G.J.J.....	1622
Tsuda, Yoshihiro.....	1166	van der Tempel, L.....	72, 1250
Tsuda, Y.....	512	Van Karsen, C.....	227
Tsui, Y.T.....	2278	Van Khang, Nguyen.....	738
Tsujiuchi, N.....	2116	Van Overmeire, M.....	2464
Tsukahara, Y.....	2477	van Rens, W.J.J.M.....	443
Tsuto, T.....	1725	van Vliet, M.....	732
Tsutsumi, Masaomi.....	1157, 1172	van Zyl, B.G.....	1622
Tu, C.V.....	866	Vanbeest, J.....	2268
Tu, Son.....	1843	Vance, J.M.....	2053
Tuah, H.....	1757		
Tucker, M.D.....	2228		
Tucker, R.....	632		
Tung, C.C.....	1314		

Vanderplaats, G.N.	1356	Walley, R.A.	1987
Vanderploeg, M.J.	2351, 2352	Walls, F.L.	1820
Vandiver, J.K.	1576	Walther, H.H.J.	443
Vanek, R.	338	Walz, J.E.	1266
Vanherck, P.	2311, 2354	Wambsganss, M.W.	651, 1292, 2008 2009, 2247
Vanmarcke, E.H.	1635	Wang, B.P.	466, 2094, 2556 2568
Varadan, V.K.	2514	Wang, B.-J.	2539
Varadan, V.V.	2514	Wang, C.Y.	655, 1295, 2236
Vasilakis, J.D.	836	Wang, D.	1399
Vasile, I.	966	Wang, I.C.	2218
Vaswani, J.	392	Wang, Jin-Wen	777
Veletsos, A.S.	907, 2005	Wang, L.R.	2015, 2142
Veluswami, M.A.	402	Wang, Pei-Chung	480
Venkatesh, V.C.	2134, 2391	Wang, Pin	2366
Venkattraman, V.	2254, 2255	Wang, Qizheng	1181
Venkayya, V.B.	1091	Wang, Shen	1910
Ventura, C.E.	907	Wang, S.S.	2064, 2291
Ventura Z., C.E.	1480	Wang, T.L.	1176, 1707
Verma, A.N.	2213	Wang, Weiji	2297
Verma, C.P.	1282, 1436	Wang, Xintian	1593
Verpoest, I.	1117	Wang, Y.K.	1294
Vestroni, F.	889, 2454	Wang, Y.L.	1205
Vianna, M.L.	1629	Wang, Y.Z.	1555
Viaro, U.	927	Wang, Zhen-ni	1688, 2304
Vigneron, F.R.	1671, 1826, 2068 2363	Wang, Zhifan	2516
Vijayakumar, P.S.	2152	Wang, Zhijun	2386
Villaverde, R.	1527, 2140	Wang, Z.	1869
Ville, J.M.	2249	Warburton, G.B.	96
Vincent, R.	2169	Ward, C.	31
Virgin, L.N.	189	Ware, A.G.	1074, 2242, 2243
Virtuoso, F.B.E.	623	Warnaka, G.E.	423
Vlad, I.	971	Warner, P.C.	368
Vlutters, A.M.	206	Warren, G.E.	247
Vogt, E.	67	Washburn, K.B.	1514
Vokurka, K.	2501	Washio, S.	146
Vold, H.	2070, 2544	Wasserman, J.F.	2423
Volker, E.	2343	Watanabe, K.	1657
von Flotow, A.H.	2487	Watanabe, T.	69
von Kerczek, C.H.	1608	Waterhouse, R.V.	169
Von Winkle, W.A.	872	Waters, J.P.	2078
Vossoughi, J.	543	Watkinson, P.S.	2265
Vu, B.Q.	119	Watson, A.P.	434
Vullo, V.	102, 2402	Watson, L.T.	1689, 1848
Vuong, I.	2169	Wattar, F.	545
Waas, G.	765	Watts, G.R.	335
Wacker, K.	656	Wawa, J.C.	135
Wada, B.K.	1008	Weaver, D.S.	653, 2480
Wada, H.	96, 1581	Weaver, H.J.	2506
Wada, S.	1254	Weaver, W., Jr.	841
Wagner, P.	136, 137, 1286	Webber, W.R.S.	2521
Walker, R.A.	1229	Webster, J.J.	89
Walker, W.J.	686, 1012	Wechsler, M.B.	616
Walkington, N.J.	1463	Weck, M.	863
Wallace, C.E.	108	Weese, W.	2111
Wallace, P.	1957	Wei, J.-C.	2218
Waller, H.	2106	Wei, M.L.	2209, 2218
		Weiger, G.	716
		Weihua, Tai	1579

- W -

Waas, G.	765
Wacker, K.	656
Wada, B.K.	1008
Wada, H.	96, 1581
Wada, S.	1254
Wagner, P.	136, 137, 1286
Walker, R.A.	1229
Walker, W.J.	686, 1012
Walkington, N.J.	1463
Wallace, C.E.	108
Wallace, P.	1957
Waller, H.	2106

Weiner, D.....	974	Wittig, L.E.....	1204
Weiss, G.H.....	263	Wittmann, R	778
Weisshaar, T.A.....	1542	Wittrick, W.H.....	377, 1739
Weitsman, Y.....	1815	Wohlbruck, R.....	535
Weizhong, Z.....	2135	Wolanski, Z.....	1925
Welch, C.R.....	492, 496	Wolf, J.P.....	1532
Welch, M.S.....	32	Wolf, S.M.....	506
Welik, P.....	2580	Wolff, F.H.....	750
Weller, T.....	1607	Wong, Chung Lun.....	882
Wellford, L.C., Jr.....	404	Wong, F.S.....	1803
Wells, W.R.....	51	Wood, J.J.....	798
Welsh, M.C.....	1451	Wood, R.M.....	44
Wen, Yi Kwei.....	549, 960	Wood, W.L.....	2107
Wenbo, Zhou.....	1222	Woodall, T.D.....	2601
Wendler, B.....	2161	Woodhouse, J.....	640, 641, 643
Weng, W.T.....	24	Woodson, S.C.....	459
Wensel, R.....	1260	Woodward, R.L.....	1971
Werkle, H.....	1530	Wright, J.R.....	2528
Werner, S.D.....	285, 937	Wu, Huile.....	2386, 2387
Wesley, D.A.....	989	Wu, Jian-ji.....	2403
West, W.M.....	2339	Wu, Longwu.....	2129
Westerberg, G.....	7, 10	Wu, L.....	2288
Westermo, B.D.....	676	Wu, M.C.....	307
Weston, D.E.....	1085	Wu, Qi-Ya.....	777
Wettschureck, R.....	1190	Wu, S.M.....	948, 2309
Whiffen, M.C.....	568	Wu, S.Y.....	141
White, C.W.....	292	Wu, T.T.....	2612
White, H.....	1674	Wu, W.F.....	2097
White, H.G.....	496	Wu, W.Z.....	596, 2440
White, K.P., Jr.....	303	Wu, Zhacteng.....	2189
Whitman, R.V.....	151, 912	Wustmann, G.....	224
Wick, A.....	2062	Wuzhou, H.....	1422
Wickens, R.H.....	356	Wyber, R.J.....	167
Wicks, A.L.....	2544	Wynne, E.C.....	791
Wiebe, D.J.....	1839		
Wight, J.K.....	1376, 1972	- X -	
Wihstutz, V.....	2101		
Wijeyewickrema, A.....	1897	Xi, Dechang.....	349, 1656
Wikstrom, B.-O.....	342	Xi-Cheng, Zhang.....	91
Williams, E.G.....	158, 873, 1287	Xu, Jianxue.....	930
Williams, F.W.....	1045, 1264, 1417	Xu, Mingtao.....	2367
	1683, 1850, 1851	Xu, Qingyu.....	2211
Williams, G.C.....	94	Xu, Zhandi.....	2301
Williams, J.P.....	1326	Xu, Zhengchang.....	801
Williams, M.H.....	679		
Williams, R.....	2070	- Y -	
Williams, R.S.....	720		
Willis, C.M.....	1215	Yadav, H.S.....	1637
Willshire, W.L.....	667	Yagoubian, J.....	2426
Wilmert, K.D.....	1735	Yajima, Nobuyuki.....	1547
Wilmhurst, T.H.....	2328	Yamada, G.....	635, 548, 849
Wilson, E.L.....	1353		1442, 1589
Wilson, G.L.....	468	Yamada, H.....	1628
Wilson, J.C.....	953, 1882	Yamada, Y.....	76
Wilson, J.S.....	2596	Yamaguchi, H.....	124
Wilson, L.O.....	2330	Yamaguchi, J.....	783
Wilson, M.W.....	2195	Yamaguchi, Kazuo...	1246, 1247, 1248
Wilson, V.L.....	2126	Yamamoto, S.....	367, 2447
Wischmann, G.....	339	Yamamoto, Toshio.....	1511, 2376
Wittig, G.....	1140	Yamamoto, T.....	768

Yamashita, S..... 1989
 Yanabe, S..... 2, 1809
 Yanai, T..... 1407
 Yanatchkov, O.P..... 654
 Yang, H.T.Y 795
 Yang, J.C.S..... 99, 503
 Yang, J.N..... 761, 956, 1865
 Yang, Kechong..... 2516
 Yang, Shuzi..... 2516
 Yang, T.Y..... 133, 1026, 2179
 2180, 2181
 Yang, W.C..... 1070
 Yang, X.G..... 948
 Yankelevsky, D.Z..... 408, 833
 Yano, S..... 192, 2044
 Yano, T..... 2012
 Yao, Yingxian..... 2361, 2532
 Yar, M..... 2279, 2315
 Yasuda, K..... 1574, 1963
 Yates, T.W..... 169
 Yazdani-Ardakani, S..... 1458
 Ye, P..... 1124
 Yeh, C.T..... 956
 Yeh, C.-H..... 2208
 Yeh, Y.-H..... 2015
 Yelle, H..... 1119
 Yen, B.T..... 1036
 Yen, S.C..... 121
 Yerges, L.F..... 752
 Yi, Huang..... 1648
 Yildiz, A..... 1277
 Yim, Kyung Bin..... 5
 Yim, S.C.-S..... 762, 962
 Yin, B..... 1314
 Yin, R.K..... 187
 Yin, Xuegong..... 2193, 2527
 Ying, J..... 66
 Yoerkie, C..... 1368
 Yokomichi, I..... 195, 473
 Yokoyama, T..... 1979
 Yoneya, T..... 1315
 Yoneyama, T..... 542
 Yoo, W.S..... 2103
 Yoshida, K..... 2029
 Yoshimura, T..... 702, 2437
 Yoshioka, T..... 243
 Young, J.C..... 334
 Young, K.D..... 1855
 Young, T.H..... 1049
 Younis, C.J..... 1960
 Yu, Hui Ran..... 2404
 Yu, I.-W..... 2270
 Yu, J.C..... 173
 Yu, T.X..... 1047
 Yuan, Jingxia..... 1171, 2309
 Yuen, M.M.F..... 1492, 2603
 Yuen, W.Y.D..... 866
 Yuhki, Y..... 473

Yum, Sung Ha..... 2281, 2460
 Yum, Y.-H..... 2234
 Yung, J.-Y..... 81

- Z -

Zachary, L.W..... 198, 199
 Zadoks, R.I..... 1410
 Zahir, M.I..... 652
 Zahrah, T.F..... 1185
 Zaretsky, E.V..... 1936, 1253, 2446
 Zarka, J..... 2293
 Zaschel, J..... 1487
 Zaveti, K..... 1669
 Zavadney, L.D..... 2275
 Zdravkovich, M.M..... 834
 Zeid, A..... 929
 Zeiger, G..... 947
 Zelicovici, J..... 2587
 Zemin, P..... 2131
 Zengyan, H..... 2246
 Zenker, P..... 1570
 Zeuch, W.R..... 1295, 2236
 Ze-min, Peng..... 1169
 Zhang, De-Wen..... 2296
 Zhang, F..... 1217
 Zhang, Hui Jiao..... 2397
 Zhang, Lingmi..... 2551
 Zhang, L..... 2312
 Zhang, P.Q..... 499, 2201, 2303
 2307
 Zhang, Ruo-jing..... 2370
 Zhang, Si..... 2133
 Zhang, Weiwei..... 1561
 Zhang, Wenbi..... 309
 Zhang, W..... 2119
 Zhao, C.-S..... 2190
 Zhao, Ling-Cheng..... 2296
 Zhao, Xing..... 2516
 Zhen, Yan..... 1222
 Zheng, Xiulin..... 1813
 Zheng, Zhao-chang.. 2370, 2403, 2562
 Zhou, Hongye..... 1519
 Zhou, Jing..... 1187
 Zhou, Ji-xun..... 441
 Zhu, Jimei..... 1535
 Zhu, Shijing..... 2183, 2297
 Zhu, Shi-Jin..... 2269
 Zhuang, Xirong..... 1259
 Zienkiewicz, O.C..... 964, 1184
 Zillmer, S.D..... 1586
 Zimmer, S..... 1342
 Zimmerman, G P..... 184
 Zimmerman, R..... 1336
 Zui, H..... 2533
 Zwaan, R.J..... 995, 1219
 Zwicke, P.E..... 720

SUBJECT INDEX

- A -

Absorbers (equipment)
1554, 1555,

Absorbers (materials)
707

Acceleration measurement
229, 903, 1820

Accelerometers
708, 2327, 2537, 2540, 2596

Acoustic absorption
324, 391, 393, 380, 585, 627, 664, 707, 1081, 1297, 1299, 1450, 1617, 2018, 2260, 2261

Acoustic emission
207, 223, 232, 233, 242, 243, 246, 253, 427, 483, 505, 506, 720, 915, 916, 1341, 1498, 1785, 1811, 1821, 2497

Acoustic excitation
108, 136, 137, 465, 1296, 1771, 2029

Acoustic fatigue
314, 997, 2534

Acoustic holography
158, 873

Acoustic imaging
1911

Acoustic impedance
395, 442, 443, 2262

Acoustic insulation
954, 1523, 1628, 1886, 2138, 2168

Acoustic intensity method
171, 489, 670, 994, 1086, 1287, 1620, 1622, 1625, 1631, 1668, 2071, 2256, 2265, 2460

Acoustic linings
69, 421, 659, 1273, 1297, 1617

Acoustic measurement
707

Acoustic properties
181, 431, 663, 1614, 1624

Acoustic resonances
1291

Acoustic resonators
156

Acoustic response
669, 1780, 1786, 1985, 2166

Acoustic scattering
167, 168

Acoustic signatures
1343

Acoustic tests
686, 1139, 1626, 2419, 2420, 2421, 2422, 2499, 2573, 2574

Acoustic waves
2483

Active attenuation
664, 2028

Active control
62, 761, 1855, 2216

Active damping
469, 689, 936, 1040, 1477, 1915

Active flutter control
689, 1730

Active force control
63, 2433, 2434

Active isolation
346, 537, 683, 1238

Active noise control
664, 1081, 1786, 2028

Active structural modification
2570

Active vibration control
228, 346, 363, 586, 588, 689, 744, 1239, 1738, 1879, 1880, 2057, 2162, 2176, 2413, 2432, 2437, 2445

Active vibration isolation
1923

Actuators
426, 2254, 2255, 2277

Added mass effects
25

Adhesives
901, 1035

Aerodynamic characteristics
790, 791, 792, 1028, 1247, 1248, 1733

Aerodynamic coefficients
1246

Abstract
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Aerodynamic damping	Alignment
352, 814	2, 1364
Aerodynamic loads	Aluminum
44, 311, 312, 317, 356, 358, 387, 393, 491, 578, 678, 793, 795, 817, 991, 998, 1216, 1217, 1219, 1249, 1357, 1731, 1743	199, 206, 207, 208, 479, 696, 1038, 1053, 1919, 1928, 2165
Aerodynamic stability	Amplitude attenuation
880, 1740, 2375	681
Aerodynamics characteristics	Amplitude measurement
313	1325, 1821, 2079
Aeroelasticity	Analog simulation
743, 1231, 1704	1467
Agricultural machinery	Annular plates
27, 1191	399, 639, 1282, 1436, 1775
Air bags (safety restraint systems)	Antennas
315	411, 1546, 2159, 2211, 2357
Air blast	Anthropomorphic dummies
1206, 2504	31
Air conditioning equipment	Approximation methods
13, 1081, 1701, 1702	303, 430, 462, 508, 1663, 1907, 1993, 2447
Air launched missiles	Arch dams
2420	1186, 1717, 1718
Aircraft engines	Arches
1545, 1741	619, 626, 1983
Aircraft fuselages	Articulated vehicles
1541	601, 777
Aircraft noise	Artillery fire
39, 41, 337, 567, 568, 569, 570, 571, 572, 573, 574, 575, 582, 1000, 1001, 1213, 1214, 1215, 1544, 1783, 1911, 2410, 2412	1623
Aircraft propellers	Asymmetric structure
797, 1560	1634
Aircraft vibration	Asymptotic approximations
311, 312, 319, 2411	170, 513, 1411, 2056, 2065, 2101, 2036
Aircraft wings	Asymptotic series
42, 43, 44, 45, 46, 317, 393, 579, 794, 795, 796, 995, 1216, 1217, 1219, 1220, 1221, 1730, 1731, 2408, 2409	2102
Aircraft	Audio frequencies
40, 47, 48, 313, 314, 316, 530, 576, 577, 578, 790, 791, 792, 793, 817, 994, 996, 997, 998, 999, 1002, 1218, 1222, 1336, 1338, 1542, 1644, 1726, 1727, 1728, 1729, 1912, 1913, 1930, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2407, 2463	1038
Airfoils	Automobile bodies
188, 364, 678, 679, 884, 1090, 1563, 1731, 2271	1543, 2403
Airports	Automobile engines
582	801, 1553
Automobiles	Automobile noise
783, 798, 1236, 1954, 2062, 2386, 2552	2402
Abstract	Autoparametric response
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615	1414
Volume 18	
Issue:	1 2 3 4 5 6 7 8 9 10 11 12

Autoregressive/moving average models	
1688, 2406	
Averaging techniques	
1467	
Axial excitation	
89, 189, 274, 300, 850, 1050, 1202, 1269, 1270	
Axial force	
1041, 1260, 1980	
Axial vibration	
2, 1572	
Axial vibrations	
2108	
Axisymmetric vibrations	
1436, 1068, 1182, 1282, 1776	
- B -	
Backlash effects	
1809	
Baffles	
107, 259, 585, 651, 2498	
Balancing machines	
502	
Balancing techniques	
501, 534, 719, 1258, 1838, 1839, 1840, 2089, 2090, 2607, 2608	
Ball bearings	
74, 75, 366, 538, 594, 1158, 1511, 1746, 2383, 2444, 2605	
Ball screw type dampers	
2058	
Balls	
2605	
Band saws	
596, 1881, 2440	
Bars	
372, 373, 606, 607, 608, 799, 825, 1384, 1580, 1581, 1641, 1960, 1966, 1981, 2196, 2197, 2198	
Base excitation	
540, 762, 840, 1195, 1480, 1870, 1975, 2363	
Base isolation	
65, 587, 685, 807, 808, 809, 810, 811, 812, 1018, 1240, 1374, 1924, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431	
Beams	
86, 87, 88, 90, 91, 93, 237, 238, 345, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 417, 539, 610, 611, 612, 613, 614, 615, 616, 618, 619, 620, 631, 702, 704, 705, 827, 828, 831, 832, 833, 841, 844, 1000, 1003, 1041, 1042, 1044, 1045, 1046, 1047, 1162, 1263, 1264, 1265, 1266, 1412, 1413, 1414, 1415, 1416, 1418, 1419, 1420, 1583, 1587, 1615, 1643, 1655, 1656, 1659, 1760, 1761, 1762,	
Beams (cont'd.)	
1763, 1765, 1828, 1880, 1902, 1925, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1976, 2202, 2203, 2204, 2205, 2206, 2259, 2256, 2283, 2380, 2436, 2456, 2457, 2458, 2479, 2603, 2606	
Beam-columns	
370, 767, 1043, 1584, 1978, 2191	
Beam-plate systems	
1100	
Bearings	
1396, 1400, 1747, 1748, 1937, 2185, 2343, 2445	
Bellows	
2019	
Bells	
649, 2234	
Belt conveyors	
1570, 1881	
Belts (moving)	
596	
Bending	
1971	
Berger theory	
1605	
Bernoulli-Euler method	
88, 830, 1264, 1739, 1765	
Bibliographies	
7, 10, 311, 312, 416, 449, 713, 991, 1236, 1320, 1860, 1922, 2061, 2087, 2497	
Bicycles	
1537	
Bifurcation theory	
189, 262, 265, 316, 734, 1842, 1843, 1844, 1945	
Biot theory	
1624, 1892	
Bird impact	
1934	
Bispectral Analysis	
33	
Blade loss dynamics	
1562, 1870	
Bladed disks	
276, 278, 353, 476, 1361, 1557, 1933, 1935, 2183	
Blades	
69, 92, 350, 357, 591, 1031, 1032, 1242, 1243, 1246, 1247, 1248, 1558, 1563, 1929, 1932, 2060, 2182, 2440	
Blade-vortex interaction	
815	

Abstract

Numbers: 1-271 272-531 532-742 743-942 940 1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Blast effects
 2040

Blast excitation
 456

Blast resistant structures
 184, 459, 460, 461, 1194, 1306, 1307, 1309, 1310, 1597,
 2041

Blast response
 26, 408, 1308, 1439

Blowdown response
 2013

Blowers
 7

Bodies of revolution
 1441, 1589

Boilers
 1535

Bolted joints
 78, 79, 212, 2191

Bolts
 1956, 1957, 2450

Bond graph technique
 283, 284, 301, 418, 426, 514, 515, 516, 517, 519, 528, 928,
 929, 932, 1070, 1501, 2569

Booster rockets
 329

Boundary condition effects
 606, 617, 1285, 1430, 1944, 1988, 1995, 2218, 2470, 2564,
 2568

Boundary element technique
 520, 1385, 1532, 1712, 1713, 1763, 2106, 2350, 2394

Boundary integral equation method
 2418

Boundary value problems
 260, 432, 724, 725, 1426, 1764, 1893

Bounded structures
 1286

Box beams
 126

Box type structures
 684

Braces
 603

Brakes (motion arresters)
 1909

Cables
 417, 604, 619, 824, 1039, 1261, 1262, 1409, 1410, 1411,
 1498, 1575, 1576, 1577, 1578, 1674, 1756, 1757, 1758,
 2454, 2455

Calibrating
 497, 708, 1818

Cantilever beams
 12, 95, 96, 391, 829, 1040, 1048, 1049, 1528, 1585, 1805,
 1975, 1977, 2121, 2201

Cantilever blades
 92

Cantilever plates
 129, 403, 1064, 1283, 1600

Cantilever shells
 1443

Cantilevers
 1492, 1524, 1638, 1829, 2017, 2245, 2532

Caps
 1603, 1604

- C -

Abstract
 Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Carbon	Clearance effects
233	2123
Cardan shafts	Clearence effects
4	2192, 2348
Cargo ships	Clutches
309, 788, 789, 1209	748
Cargo transportation	Coanda effect
1134, 2579	414
Cascades	Coefficient of friction
69, 352, 358, 1028, 1029, 1031, 1561, 1562, 1563, 2128	1749
Case histories	Coherence function technique
1677, 1678, 1747, 2008, 2159, 2172, 2208, 2235, 2242,	518, 1150, 1151, 1152, 1153, 1154, 1155, 2544, 2549
2243, 2258, 2287, 2290, 2339	
Catenaries	Collision research (ships)
1261	31, 55, 56, 303, 786, 1908, 563
Cavitation	Columns
451, 1207, 1744, 1797, 2052, 2092	25, 621, 622, 1050, 1051, 1269, 1270, 1766, 1767, 1891,
Centrifugal compressors	1980
1509, 1510	Combined systems
Centrifugal forces	510
2089	Combustion engines
Centrifugal pumps	174, 716
1366, 1703	Combustion excitation
Centrifuges	2253
946 1365	Combustion noise
Cepstrum analysis	2250
2518	Compaction equipment
Ceramics	27, 985
382	Complex modulus
Chains	1035, 1079, 1128, 1148, 1149
824, 1516	Complex structures
Chatter	1501
751, 1170, 1874, 1875, 1877, 1878, 2132, 2187	Component mode analysis
Chimneys	610, 841, 1329, 2526
291, 1891	Component mode synthesis
Circuit boards	486, 1330, 1331, 1521, 1827, 1828, 1902, 2069, 2072, 2074,
2491, 2492, 2494	2125, 2257, 2370, 2512, 2533
Circular bars	Composite beams
1582	94
Circular cylinders	Composite materials
98, 99, 387, 644, 645, 813, 834, 835, 836, 838, 1267, 1647	233, 234, 697, 1053, 1106, 1108, 1109, 1110, 1223, 1473,
Circular plates	1662, 1777, 1785, 1997
131, 132, 397, 404, 1060, 1061, 1062, 1182, 1280, 1281,	Composite structures
1437, 1776, 1994, 2215, 2471, 2472, 2473, 2474, 2502	45, 46, 106, 121, 132, 153, 406, 632, 1052, 1061, 1062,
Clays	1128, 1133, 1279, 1430, 1440, 1919
294	Compressor blades
	814, 1502, 1741

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Compressors	Contact vibration
8, 282, 1125, 1508, 1699, 1700, 1701, 1702, 2127, 2128	1188, 1189, 1645
Computer aided design	Containment structures
2170, 2435	561, 1719
Computer aided techniques	Continuous beams
712, 721, 842, 1793, 1951, 2382, 2590, 2598, 2599, 2604	830
Computer graphics	Continuous parameter method
625	516, 739, 924, 1040, 1097, 1233, 2346
Computer programs	Continuous systems
45, 55, 188, 270, 271, 286, 295, 325, 393, 401, 525, 526, 527, 528, 529, 530, 554, 560, 565, 575, 599, 655, 656, 671, 741, 742, 743, 815, 835, 836, 914, 945, 988, 1063, 1098, 1159, 1243, 1295, 1356, 1357, 1359, 1360, 1386, 1423, 1524, 1667, 1704, 1705, 1718, 1728, 1746, 1761, 1816, 1834, 1860, 1863, 1904, 1908, 1913, 1987, 2001, 2013, 2038, 2051, 2103, 2111, 2112, 2113, 2129, 2164, 2223, 2268, 2340, 2365, 2389, 2407, 2435, 2444, 254 ² , 2557, 2558, 2559, 2561, 2586, 2587, 2599, 2614	191
Computer storage devices	Continuum mechanics
154	1123
Computer systems hardware	Control simulation
2256, 2519	1853
Computerized simulation	Control systems
283, 284, 416, 877, 1071, 1728	1732, 2027
Computer-aided techniques	Cooling towers
236, 251, 719, 1337, 2110, 2334, 2499, 2576	963, 1438
Concentric structures	Coriolis forces
146, 410, 1781	591, 1931
Concrete	Correlation techniques
295, 407, 424, 455, 553, 554, 672, 977, 981, 1146, 1186, 1462, 1482, 1529, 1658, 1709, 1814, 1967	2199, 2324, 2528
Conformal mapping	Corrosion fatigue
1052, 1427	481
Conical bodies	Cosserat point
539	1650
Constitutive equations	Coulomb damping
674, 1146, 1148, 1899, 1900	685, 1959
Constrained structures	Coulomb friction
87, 742, 1350, 1504, 1651	152, 155, 278, 629, 733, 896, 897, 898, 1007, 1114, 1245, 1361, 1478, 1762, 1810, 1915, 1929, 2060, 2283, 2284, 2285, 2509
Constraint function technique	Coupled response
1695	95, 272, 328, 369, 465, 944, 1032, 1286, 1862, 2108, 2318, 2457
Constraint modes method	Coupled systems
1328, 1898, 2011, 2557	1414
Construction industry	Couplings
448	1571
Contact stresses	Crack detection
1253	245, 247, 717, 718, 915, 1141, 1142, 1953, 2337
Abstract	Crack propagation
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615	80, 203, 204, 206, 213, 215, 246, 247, 477, 478, 479, 482, 483, 506, 698, 900, 915, 1115, 1116, 1120, 1121, 1187, 1221, 1226, 1324, 1657, 1813, 1814, 2217
Volume 18	Cracked media
Issue: 1 2 3 4 5 6 7 8 9 10 11 12	217, 1181, 1444, 1481, 1579, 1659, 1765, 1815, 1863, 2098

Cranes (hoists)
950, 1192, 1193, 2136

Crankshafts
801, 1164

Crash research (aircraft)
756, 757, 770, 860, 876, 1223

Crash victim simulation
55, 56

Crashworthiness
988

Critical damping
1097, 2056

Critical excitation method
676

Critical loads
1584

Critical speeds
785, 787, 1037, 1165, 1166, 1602, 1867, 1868, 1869, 1937, 1945, 2374, 2376

Critical stress identification
1689

Cryogenic systems
561

Curve fitting
2308, 2322

Curved beams
1445, 1764, 2177

Curved pipes
2482

Cutting
253, 948, 1875, 1876, 2131

Cyclic loading
59, 89, 104, 294, 355, 370, 388, 561, 602, 603, 622, 638, 768, 769, 964, 1020, 1146, 1482, 1529, 1580

Cylinders
97, 100, 101, 102, 147, 654, 837, 1212, 1268, 1291, 1421, 1422, 1512, 1588, 1589, 1641, 1979, 2011, 2260

Cylindrical bearings
1252, 2184

Cylindrical bodies
843

Cylindrical shells
136, 137, 138, 139, 140, 142, 499, 543, 640, 641, 642, 643, 850, 1288, 1443, 1444, 1606, 1607, 1780, 1871, 1986, 1997, 2003, 2004, 2122, 2230, 2231, 2232, 2233, 2475, 2477, 2502

Dam bearings
1939

Damage detection
2606

Damage prediction
457, 547, 878, 1375

Damped modes
933

Damped structures
865, 887, 1065, 1331, 1432, 1480, 1503, 1869, 1991, 2020, 2226, 2256, 2284, 2285, 2288, 2456

Damped systems
886

Damper locations
1554

Dampers
326, 683, 888, 1000, 1479, 2058, 2287

Damping characteristics
818, 1099

Damping coefficients
20, 84, 99, 199, 320, 371, 375, 550, 593, 595, 688, 693, 768, 805, 894, 895, 909, 934, 935, 936, 952, 1002, 1019, 1030, 1069, 1074, 1075, 1077, 1172, 1254, 1294, 1335, 1348, 1396, 1397, 1398, 1422, 1429, 1565, 1596, 1654, 1691, 1692, 1748, 1767, 1940, 1944, 1946, 1949, 2017, 2124, 2129, 2191, 2192, 2242, 2243, 2281, 2282, 2371, 2385, 2391, 2472, 2494, 2510

Damping effects
18, 25, 197, 277, 347, 357, 611, 636, 692, 1009, 1055, 1170, 1656, 1704, 2280, 2378, 2381

Damping
684, 2054

Dams
295, 454, 553, 771, 772, 773, 774, 775, 982, 983, 984, 1187, 1389, 1390, 1391, 1534, 1715, 1716, 1902, 2144, 2395, 2396

Data dependent systems
231, 2306

Data processing
303, 504, 518, 1491, 2307, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551

Data recorders
1338

Deconvolution technique
1711, 2318

Design sensitivity analysis
2302

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Design techniques
 6, 286, 325, 422, 461, 472, 638, 684, 699, 746, 754, 820, 863, 972, 996, 1002, 1006, 1009, 1012, 1099, 1165, 1309, 1453, 1505, 1943, 1951, 1952, 2125, 2130, 2404, 2586

Detectors
 1130, 1131, 2535

Diagnostic instrumentation
 252, 1342, 1343

Diagnostic techniques
 237, 238, 239, 240, 241, 242, 243, 244, 246, 247, 499, 913, 914, 990, 1136, 1137, 1138, 1342, 1493, 1494, 1674, 1675, 1676, 1677, 1678, 1835, 1836, 1837, 1885, 2086, 2088, 2335, 2336, 2337, 2338, 2603, 2604, 2605, 2606

Diesel engines
 37, 201, 239, 240, 241, 248, 541, 1167, 1363, 1725

Difference equations
 2525

Digital filters
 1486, 1487

Digital techniques
 225, 1487, 1953, 2028, 2499, 2536, 2581, 2595

Direct computational method
 72

Direct integration technique
 1868, 2136

Discontinuity-containing media
 237, 238, 474, 602, 838, 1096, 1181, 1324, 1433, 1773, 2203, 2292, 2295

Discrete Fourier transform
 907, 1480

Disk drives
 2257, 2258

Disks
 279, 747, 913, 1059, 1160, 1435, 1545, 2377, 2383, 2462, 2472

Displacement analysis
 1728, 2357

Displacement measurement
 60, 225

Dissipation factor
 1943

Donnell's theory
 2233

Doors
 184, 1306, 1307

Doubly asymptotic approximation
 135, 682

Drag coefficients
 100, 1576

Drilling platforms
 559, 1675, 1720, 1722, 1723, 2136, 2335, 2400

Drilling
 1548, 1549, 1873

Drills
 605, 1173, 1665

Driveline vibrations
 2386, 2387

Drop tests (impact tests)
 1455

Ducts
 148, 176, 421, 422, 423, 659, 660, 664, 861, 1081, 1296, 1448, 1449, 1450, 1451, 1612, 1613, 1614, 1769, 2023, 2024, 2123, 2150, 2248, 2249, 2250, 2251, 2252, 2253, 2483, 2484

Duffing oscillators
 261, 1345, 1466, 1764, 2315

Duffing's differential equation
 267, 2093

Duhamel integral
 2273

Dynamic absorbers
 344, 345

Dynamic balancing
 1679

Dynamic buckling
 385, 603, 1060, 1066, 1603, 1891

Dynamic calibration
 491

Dynamic coefficients
 2443, 2452, 2453

Dynamic condensation technique
 501, 2530, 2130

Dynamic plasticity
 1643

Dynamic properties
 1440

Dynamic relaxation
 2129

Dynamic stability
 123, 779, 1050, 1192, 1193, 1443, 1585, 1947

Dynamic stiffness method
 191

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1158 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Dynamic stiffness	Elastic restraints
103, 828, 895, 1035, 1264, 1377, 1397, 1893	730, 1285, 1584, 1776, 1778
Dynamic structural analysis	Elastic supports
531, 2614	381, 386, 397, 535, 657, 1280, 1365, 1978, 2037
Dynamic tests	Elastic systems
184, 968, 2025, 2082	190, 1348, 1766, 2046, 2567
Dynamic vibration absorption (equipment)	Elastic waves
800, 1025	717, 718, 731, 921, 1268, 1351, 2203, 2292, 2295, 2310
Dynamometers	Elastodynamic response
716	83, 128, 256, 1579, 2198
- E -	
Ears	Elastohydrodynamic properties
1016	71, 72, 142, 1748
Earthquake damage	Elastomeric dampers
139, 187, 457, 547, 1375, 2105, 2142	1103
Earthquake prediction	Elastomers
673	59, 66, 209, 210, 211, 347, 806, 809, 973, 1019, 1020, 1237, 1260, 1395, 1748, 1962, 2062, 2424, 2430, 2439, 2451
Earthquake resistant structures	Electric components
1709, 1859, 2026	876
Earthquake response	Electric motors
412, 458	1136, 1137
Earthquake simulation	Electrodynamic shakers
975	2520
Eddy current probes	Electrohydraulic shakers
1140	2333
Effective eccentricity	Electromagnetic damping
1888	687, 1100
Eigenvalue problems	Electromagnetic exciters
103, 257, 260, 637, 728, 845, 929, 1394, 1502, 1683, 1684, 1824, 1850, 1851, 1867, 2094, 2346, 2610, 2612	2045
Ejection seats	Electromagnetic properties
315, 343	1137
Elastic foundations	Electronic instrumentation
130, 833, 847, 851, 1058, 1182, 1282, 1587, 1604, 1763, 2181, 2194, 2214, 2215, 2370, 2461	715, 1821, 1833, 2449, 2492, 2493
Elastic half space	Electronic test equipment
1639	2173
Elastic media	Elevated railroads
513, 1464, 1642, 2037, 2066	1204
Elastic medium	Elevators
1043	893
Elastic plastic properties	Enclosures
268, 1047, 1271, 1593, 1640, 1660, 1768, 2065, 2293	179, 1297, 1786, 2410, 2485
Elastic properties	Energy absorption
114, 376, 507, 621, 623, 825, 965, 976, 1019, 1020, 1103, 1482, 1964, 2454	373, 1223, 1928, 2191, 2438
Energy dissipation	
776, 784, 885, 886, 1474, 1927	

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1881-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Energy methods	Expansion joints
50, 399	974, 1178
Energy transfer	Experimental data
2508, 2539	39, 117, 121, 157, 202, 249, 278, 285, 304, 305, 332, 356, 361, 401, 443, 459, 570, 580, 601, 689, 763, 840, 934, 935, 951, 952, 1179, 1188, 1271, 1299, 1306, 1307, 1376, 1379, 1558, 1560, 1563, 1572, 1632, 1710, 2008, 2009, 2040, 2057, 2124, 2152, 2331, 2406, 2414, 2444, 2452, 2453
Energy transmission	Experimental modal analysis
1055	131, 229, 230, 711, 904, 1007, 1008, 1010, 1159, 1331, 1334, 1335, 1336, 1338, 1705, 1825, 1826, 1828, 1904, 2068, 2070, 2073, 2076, 2135, 2137, 2147, 2152, 2154, 2160, 2162, 2167, 2172, 2208, 2212, 2218, 2224, 2228, 2234, 2235, 2240, 2242, 2257, 2258, 2281, 2287, 2290, 2305, 2311, 2313, 2323, 2326, 2327, 2334, 2339, 2354, 2359, 2363, 2370, 2371, 2372, 2373, 2374, 2379, 2383, 2384, 2387, 2390, 2396, 2399, 2405, 2406, 2410, 2411, 2414, 2416, 2417, 2424, 2425, 2426, 2427, 2428, 2464, 2465, 2466, 2475, 2478, 2481, 2490, 2494, 2512, 2517, 2518, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2529, 2530, 2531, 2534, 2535, 2536, 2539, 2540, 2541, 2542, 2543, 2545, 2546, 2548, 2549, 2550, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2550, 2561, 2562, 2563, 2564, 2565, 2567, 2568, 2569, 2570, 2572, 2602, 2603, 2604, 2607, 2608, 2609
Engine mounts	Experimental test data
1553	1933
Engine noise	Expert systems
1618	1816
Engine vibration	Explosion effects
574	461, 968, 2040, 2268, 2503, 2504
Environment simulation	Explosives
1013	1800
Environmental effects	Extensional deformation effects
1833	650
Equations of motion	Extensional waves
507, 736, 947, 1132	1111, 1128
Equipment mounts	External damping
324	691
Equipment response	Extremum principles
1133, 1197, 1633	925
Equipment-structure interaction	Failure analysis
185, 940, 1087, 1240, 1527, 1794, 2140, 2426, 2489	238, 1836
Equivalent linearization method	Failure detection
404, 685, 1374, 1380, 1434, 1502, 1982	246, 503, 1138, 1139, 1140, 1492, 1493, 1494, 1674, 1785, 2335, 2339, 2605
Equivalent plate analysis method	Fan blades
2409	70, 1557, 1741, 1840, 1933, 1934
Equivalent viscous damping	Fan noise
79	2123
Error analysis	Abstract
96, 529, 598, 1150, 1151, 1152, 1153, 1154, 1155, 1614, 1669, 2079, 2107, 2265, 2317, 2323, 2374, 2536, 2547, 2554, 2613	Numbers: 1-271 272-531 532-742 743-842 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615
Euler equation	Volume 18
1964	Issue: 1 2 3 4 5 6 7 8 9 10 11 12
Euler-Lagrange equation	
1499	
Exact methods	
646	
Excavators	
2397	
Excitation techniques	
2240	
Exhaust systems	
280, 475, 2481	

- F -

Abstract

Numbers: 1-271 272-531 532-742 743-842 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Fans	Finite element techniques (cont'd)
7, 357, 1514, 1677, 1705	2257, 2270, 2272, 2300, 2302, 2313, 2345, 2380, 2396, 2404, 2405, 2441, 2457, 2490, 2530, 2553, 2564, 309
Fast fourier transform	Flexibility coefficients
178, 905, 1071, 1096, 1485, 1488, 1664, 1759, 1852, 2611	5, 1675
Fasteners	Flexible foundations
1955, 2450	552, 763, 1869
Fatigue life	Flexible rotors
47, 52, 73, 80, 81, 82, 108, 200, 201, 202, 203, 204, 206, 207, 208, 209, 210, 211, 212, 214, 215, 246, 350, 351, 355, 474, 478, 479, 480, 481, 482, 483, 503, 544, 545, 558, 559, 602, 695, 696, 697, 698, 699, 796, 899, 902, 955, 1033, 1034, 1036, 1113, 1115, 1116, 1117, 1118, 1120, 1121, 1138, 1176, 1188, 1227, 1253, 1256, 1265, 1324, 1363, 1481, 1494, 1513, 1545, 1657, 1658, 1659, 1746, 1811, 1812, 1813, 1906, 1936, 1953, 1956, 1957, 2019, 2023, 2062, 2063, 2064, 2195, 2289, 2290, 2291, 2446, 2449, 2481, 2491, 2512, 2597	
Fatigue tests	Flexible shafts
81, 205, 216, 475, 476, 477, 618, 701, 901, 1116, 1119, 1189, 1221, 1226, 1256, 1721, 1729, 2062, 2446, 2584	2383
Feedback control	Flexural stiffness
2027	41, 604
Fiber composites	Flexural vibrations
632, 1048, 1106, 1109, 1124, 1429, 1873, 2064, 2165, 2291, 2502, 2511, 2514	19, 113, 115, 119, 120, 278, 369, 396, 398, 500, 596, 614, 630, 634, 831, 832, 848, 944, 1045, 1052, 1057, 1058, 1059, 1060, 1061, 1062, 1064, 1256, 1256, 1257, 1263, 1274, 1278, 1384, 1426, 1431, 1507, 1568, 1582, 1586, 1598, 1751, 1762, 1763, 1881, 1960, 1973, 1976, 1993, 2115, 2121, 2210, 2214, 2384, 2387, 2459, 2467, 2469
Fiber optics	Flexural waves
1132, 2535	77, 86, 1096, 1111, 1412, 1760, 2203
Fiberglass	Flight simulation
2330	206
Field test data	Flight tests
2173	1125
Fifth wheel couplings	Flight vehicle equipment response
601	38, 1134
Finite difference method	Floating ring journal bearings
1259, 1313	1947
Finite difference technique	Floating structures
421, 577, 1144, 1296, 1352, 1448, 1583, 1599, 1803, 2153, 2448, 2468, 2551	835, 1207, 2148
Finite element techniques	Floors
18, 22, 45, 49, 71, 81, 102, 127, 129, 256, 268, 271, 281, 310, 383, 390, 398, 404, 406, 413, 431, 518, 522, 525, 539, 558, 614, 633, 653, 671, 690, 702, 730, 731, 741, 772, 836, 859, 913, 979, 1026, 1032, 1046, 1067, 1097, 1098, 1101, 1104, 1105, 1112, 1114, 1146, 1168, 1171, 1175, 1208, 1251, 1271, 1283, 1328, 1330, 1349, 1351, 1354, 1359, 1377, 1392, 1396, 1400, 1413, 1415, 1423, 1428, 1432, 1438, 1439, 1476, 1492, 1502, 1528, 1530, 1531, 1581, 1590, 1591, 1594, 1595, 1598, 1609, 1670, 1681, 1684, 1687, 1704, 1705, 1716, 1735, 1737, 1745, 1756, 1757, 1762, 1777, 1784, 1799, 1803, 1814, 1834, 1855, 1858, 1863, 1876, 1896, 1901, 1908, 1915, 1925, 1974, 1999, 2013, 2022, 2023, 2030, 2103, 2106, 2111, 2112, 2113, 2120, 2129, 2132, 2139, 2164, 2181, 2182, 2188, 2198, 2205, 2208, 2218, 2223, 2224, 2227, 2234, 2244, 2245,	
	Flow measurement
	369
	Flow-induced vibration
	98
	Flugge's shell theory
	1986
	Fluid elastic instability
	1069
	Fluids
	881, 1320

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Fluid-filled bearings	Forcing function
1399	681, 2415
Fluid-filled containers	Forging machinery
138, 144, 145, 156, 309, 417, 535, 536, 611, 620, 645, 657, 800, 854, 855, 1072, 1316, 1317, 1318, 1365, 1443, 1609, 1734, 1781, 1800, 2002, 2004, 2005, 2006, 2016, 2017, 2022, 2235, 2238, 2245, 2479	339, 1517, 1706, 1879
Fluid-filled media	Fossil power plants
525, 1512	914
Fluid-film bearings	Foundations
1, 943, 1160, 1564, 1940, 2370, 2372, 2373, 2379	551, 767, 1123, 1388, 1531, 1532, 1892, 1893
Fluid-induced excitation	Four bar mechanisms
48, 52, 97, 110, 144, 192, 193, 259, 291, 300, 310, 380, 415, 416, 417, 536, 556, 620, 644, 651, 652, 653, 654, 656, 679, 794, 814, 816, 834, 856, 857, 880, 884, 896, 918, 986, 990, 1069, 1072, 1073, 1082, 1093, 1094, 1095, 1201, 1222, 1242, 1262, 1288, 1290, 1319, 1451, 1469, 1508, 1509, 1510, 1561, 1562, 1576, 1588, 1608, 1611, 1613, 1741, 1769, 1770, 1979, 1989, 2008, 2009, 2010, 2011, 2016, 2019, 2022, 2230, 2238, 2241, 2245, 2246, 2247, 2271, 2278, 2462, 2471, 2480, 2482	823, 1258, 1751, 2348
Fluid-structure interaction	Fourier analysis
141, 299, 394, 450, 467, 536, 557, 655, 682, 781, 1016, 1194, 1198, 1199, 1291, 1349, 1754, 2047, 2054, 2164, 2236, 2270, 2612	1454, 2133
Fluid-structure	Fourier series
1208	379, 1485
Flutter	Fourier transformation
43, 45, 46, 70, 188, 527, 677, 821, 995, 1029, 1031, 1218, 1219, 1220, 1231, 1280, 1361, 1542, 1563, 1731, 1840, 1929, 1984, 2017, 2128, 2158, 2375	1489, 1666, 2071
Flywheels	Fracture detection
239	2342
Gearings	Fracture properties
1624, 2171	217, 271, 498, 673, 700, 780, 900, 993, 1048, 1122, 1123, 1265, 1341, 2065, 2606
Coupling forces	Framed structures
88, 1585	103, 388, 389, 425, 1200, 1272, 1423, 1526, 1887, 1890, 1981, 1982
Footings	Frames
25, 1714	104, 105, 153, 390, 624, 625, 839, 840, 841, 842, 1271, 1768, 1974, 2168, 2193, 2209, 2210, 2211, 2212, 2572
Force measurement	Free vibration
222, 903, 1242, 1672, 1754, 2040	1773
Force prediction	Freight cars
1728, 1754	1205, 1707
Force transmission	Frequency analysis
1406	637, 1674, 2092
Forced vibrations	Frequency analyzers
379, 838, 923, 1516, 1844, 2274	905
Force-state mapping technique	Frequency domain method
1406	37, 48, 240, 273, 485, 711, 881, 986, 1005, 1333, 1387, 1485, 1685, 1810, 1826, 1835, 2049, 2075, 2325, 2347, 2358, 2364, 2503, 2517, 2550
Friction	Frequency response functions
2186	1663, 1664, 1726, 2076, 2163, 2299, 2320, 2544, 2209, 2312, 2364, 2388, 2546, 2558, 2559
Friction bearings	Frequency response
2186	526, 530, 927, 1150, 1151, 1152, 1153, 1154, 1155, 1846, 1913, 2093, 2159

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
1406												

Friction excitation	Global fitting method
76	2308, 2529
Friction	Global identification technique
1260, 1796	269, 2163, 2517
Functional analysis	Grain silos
881	1528
Fundamental frequency	Granular materials
397, 466, 632, 1427, 1433, 1592, 1805, 1950, 1993, 2459,	195, 473
2469, 1977	Graphic methods
Fundamental modes	489, 625, 1026, 1364
1424	Graphite
- G -	694, 1038, 1107
Galerkin method	Green function
396, 1274, 1427, 1431, 1524, 1968, 2005, 2122, 2220	48, 259, 1422, 1425
Galloping	Grids (beam grids)
677, 1093	617, 2208
Gas venting	Grids (beams)
1397	1417
Gauss-Newton method	Grillage method
2153	112
Gear boxes	Grinding machinery
722, 1033, 1138, 1954, 2083, 2187	1877, 1878, 2135
Gear couplings	Gross spectral method
2	489
Gear drives	Ground effect machines
1507, 1678	305
Gear noise	Ground motion
1567	759, 1387, 1635
Gear teeth	Ground resonance
1138, 1402, 1678, 2188	1225, 1559
Gears	Ground shock
76, 272, 282, 367, 368, 369, 532, 597, 598, 599, 1255,	2505
1401, 1494, 1570, 1749, 1750, 1835, 1861, 1862, 1952,	Ground surface
1953, 2189, 2447	442, 443, 663, 1084, 1791
Gear-induced vibration	Ground vehicle equipment response
575	1134
Geometric effects	Ground vehicles
591, 664, 1055, 1210, 1592, 1682, 2458, 2465	301, 302, 346, 991, 1206, 1537, 1907, 2149, 2512
Geometric imperfection effects	Ground vibration
14, 400, 825, 1399	63, 456, 588, 1190, 2005, 2433, 2434
Gimbals	Guideways
2353	992
Glass reinforced plastics	Gun mounts
223	2172
Gliders	
1231	

Abstract
Numbers: 1-271 272-531 532-742 743 942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Gunfire effects	Helicopter equipment
2593, 2599	2159, 2385
Guyed structures	Helicopter noise
763, 1546, 1891	37, 336, 375, 815
Gyroscopes	Helicopter rotors
691	273, 319, 359, 361
- H -	
Half-space	Helicopter vibration
2294	744, 2413, 2414, 2599
Hamiltonian functions	Helicopters
736	38, 68, 318, 359, 360, 362, 363, 365, 722, 743, 816, 942, 1123, 1162, 1224, 1225, 1226, 1227, 1228, 1229, 1230, 1368, 1559, 1732, 1733, 1743
Hamiltonian principle	Helmets
266, 1470, 2210	2423
Hammers	Helmholtz integral method
390	390, 2106
Hardened installations	Helmholtz resonators
460	174
Harmonic analysis	Hertzian contact
703, 1852	379, 1645, 2002
Harmonic balance method	High frequency excitation
261, 272, 379, 512, 538, 610, 726, 727, 1054, 1968	2427
Harmonic excitation	High frequency resonance technique
127, 191, 332, 747, 924, 966, 1043, 1046, 1126, 1322, 1346, 1347, 1443, 1792, 1810, 1894, 1895, 1966, 1993, 2001, 2098	1496
Harmonic response	High frequency response
120, 137, 850, 891, 1432, 1444, 1468, 1718, 1892, 2043, 2102	1901
Harmonic waves	Hole-containing media
1662, 2031, 2204	205, 1324, 1598, 1779, 1987, 1996, 2024, 2467, 2475
Head (anatomy)	Holographic techniques
343, 2423	67, 129, 713, 1325, 1483, 1497, 2550
Heat exchangers	Holzer method
415, 416, 1290, 1292, 2008, 2009, 2246, 2247	1887
Heat generation	Honeycomb structures
59	108, 580, 684, 1928, 1985
Heat shields	Hopkinson bar technique
232	496, 708, 1458
Hesviside functions	Hospitals
1597	13
Helical gears	Household appliances
1256, 1256, 1257, 1567, 2448	284
Helical springs	Hugoniot equation
1556, 1739, 2178, 2428	26
Helicopter blades	Human hand
1740	54, 341, 1017, 1548, 1549

Abstract

Numbers: 1-271 272-531 532-742 743-842 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2388 2389-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Human response
 53, 66, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342,
 381, 582, 583, 584, 798, 1014, 1015, 1235, 1548, 1549,
 1920

Human spine
 343

Hunting motion
 785, 787, 1167

Hydraulic dampers
 1921

Hydraulic equipment
 146

Hydraulic servomechanisms
 2254, 2255

Hydraulic systems
 526, 656, 1832, 2385

Hydraulic turbines
 2208

Hydrodynamic coefficients
 308

Hydrodynamic excitation
 36, 147, 465, 772, 773, 872, 1212

Hydrodynamic loads
 92

Hydrodynamic lubrication
 1250, 1251

Hydrodynamic response
 2112, 2236

Hysteretic damping
 760, 774, 889, 890, 891, 892, 958, 959, 984, 1018, 1049,
 1580, 1648, 1815, 2059, 2279, 2436

- I -

Ibrahim time domain technique
 1823, 2319

Ice
 1723

Impact dampers
 195, 473, 1478

Impact excitation
 835, 923, 1263, 1275, 1593, 1664, 1965, 2002, 2098

Impact hammer tests
 230, 718

Impact limiters
 2171

Impact noise
 446, 1174, 1300

Impact response
 74, 75, 111, 122, 182, 268, 343, 376, 386, 410, 609, 621,
 671, 672, 756, 757, 770, 836, 860, 876, 1413, 1457, 1641,
 1707, 1723, 1765, 1796, 1967, 1968, 1971, 2038, 2196,
 2231, 2294

Impact tests
 304, 327, 329, 1053, 1462, 1934, 2334, 2539, 2578

Impedance technique
 663, 2225

Impulse response
 102, 372, 452, 643, 662, 669, 1286, 1458, 1638, 2004,
 2221, 2417, 2461

Impulse testing
 1110, 1795

Incipient failure detection
 2088

Indentation
 182

Industrial facilities
 175, 338, 339, 447, 449, 458, 585, 941, 1377

Inertial forces
 100, 735, 1946, 1948, 2053, 2118, 2192, 2293

Infinite element technique
 2047

Inflatable structures
 2179, 2396

Influence coefficient method
 1160, 1377, 2608

Initial deformation effects
 189, 1032, 1041, 1042

Instrumental variable method
 1691

Instrumentation
 155, 1667

Intake systems
 1837

Integral equations
 258

Integration methods
 2325

Integration
 2356

Integrodifferential equation
 2202

Interface: solid-fluid
 1787

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Interface: solid-solid	- L -
717	Lagrange equations 510, 1064, 1289, 1578, 1898, 2038, 2241, 2355
Interferometers	ce transformation 347, 532, 1581, 2098
219	Large amplitude vibrations 2463
Interferometric techniques	Lasers 234, 241, 1163, 1819, 2078, 2328
67, 129, 707, 1325, 1497, 1821	Laser-Doppler method 2262
Interior noise	Lateral response 755, 840, 2488
39, 40, 41, 573, 574, 575, 798, 994, 999, 1000, 1001, 1214, 1215, 1541, 1544, 2402, 2410	Lateral vibrations 1163, 1864, 1981
Intermittent motion	Lathes 1157, 2132
1651, 2046	Launch vehicles 328, 2415
Internal combustion engines	Launching response 330
1168, 280	Launching 1011
Internal damping	Layered damping 636, 997, 1111, 1112, 1775, 1996, 2286
41, 247, 1237, 2229, 2511	Layered materials 94, 118, 119, 122, 123, 167, 216, 217, 382, 399, 400, 614, 615, 629, 673, 799, 912, 1056, 1139, 1141, 1276, 1277, 1385, 1413, 1421, 1428, 1429, 1430, 1431, 1432, 1481, 1655, 1713, 1751, 1990, 1991, 2003, 2032, 2502
Internal forces	Least squares method 1326, 1335, 1681, 1823, 1843, 2190, 2358, 2528, 2529, 2557, 2613
136, 137, 1402	Levitation 2615
Internal pressure	Lifeline systems 2142
1903	Limit cycle analysis 257, 734, 837, 2145, 2146
Internal resonance	Line source excitation 1894, 1895
138, 864, 1414, 1467, 1471, 2353, 2376	Kron method 624
Isolators	Linear programming 1636, 2571
1237, 2175	Kryloff-Bogoliuboff method 16, 726
Iteration	Linear systems 907, 1327, 1685, 2095
522, 2349, 2530	Abstract Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615
- J -	Volume 18
Jet engines	Issue: 1 2 3 4 5 6 7 8 9 10 11 12
1114, 1834	153
Jet noise	
180, 414, 567, 568, 569, 570, 571, 2259	
Joints	
77, 370, 820, 897, 901, 1034, 1181, 1186, 1340, 1403, 1404, 1405, 1406, 1958, 1959, 2190, 2449	
Journal bearings	
71, 72, 593, 1250, 1251, 1399, 1564, 1565, 1676, 1698, 1744, 1745, 1941, 1942, 1943, 1944, 1945, 2443	
Jump phenomena	
367	
- K -	

Linearization methods	Machinery-induced vibrations
508, 732, 2552	588, 967, 2433, 2434
Linings	Machines
1450	2356
Linkages	Machining
821, 822, 823, 1259, 1751, 1960, 2277	751, 949
Linking analysis and test	Magnetic bearings
2154, 2190, 2199, 2207, 2256, 2257, 2324, 2325, 2326, 2399, 2439, 2456, 2458, 2464, 2475, 2478, 2552, 2553, 2554, 2555, 2556	537, 819, 1738
Liquid rocket propellants	Magnetic tapes
1734, 1806	1881, 1950
Longitudinal response	Magnets
1966	24
Longitudinal vibrations	Marine engines
115, 1650, 1762, 606, 1950	368, 1363, 1400
Longitudinal waves	Marine risers
1447, 1619	30, 97, 147, 310, 1588
Loosening	Masonry
2450	150, 287, 1522, 2488
Loss factors	Mass additive technique
885, 1354, 1474, 1996, 2020, 2225, 2510, 2559	2209
Lubrication	Mass coefficients
71, 72, 1753, 2186, 2446	934, 935, 936, 1422, 1691
Lumped mass method	Mass matrices
1259	1420, 1692, 1855, 2326
Lumped parameter method	Mass participation factors
262, 438, 516, 1097, 1680, 2306	255
Lyapunov functions	Mass-beam systems
1766	384, 1589, 2115, 2121
Lyapunov's method	Mass-plate systems
1680	2473
Machine diagnostics	Matched asymptotic expansion technique
2336, 2342	2202
Machine foundations	Material damping
63, 969, 971, 972, 973, 974, 975, 976, 977, 979, 980, 981, 1019, 1024, 1025, 1103, 1555, 2435	198, 468, 470, 472, 694, 1001, 1002, 1010, 1107, 1108, 1109, 1110, 1133, 1919, 2511
Machine tools	Materials handling equipment
253, 916, 1021, 1169, 1170, 1171, 1172, 1518, 1665, 1873, 1876, 2130, 2131, 2132, 2133, 2134, 2389, 2390, 2391, 2535, 2547	752, 1371
Machinery noise	Mathematical models
665, 666, 1453, 1620, 2263	174, 283, 284, 301, 328, 343, 385, 516, 517, 518, 519, 571, 688, 742, 822, 932, 950, 977, 998, 1094, 1108, 1123, 1157, 1233, 1234, 1352, 1387, 1503, 1854, 1856, 2126, 2179, 2367, 2423, 2442, 2569
Machinery vibration	Matrix methods
1552, 1816, 1872	828, 833, 1264, 1362, 1691, 1692, 1914, 2611
Matrix reduction methods	2390, 2554

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1506 1508-1895 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Maximum entropy spectral analysis	Mines (excavations)
296	1570
Maximum likelihood method	Minimization technique
530	2153
Mean square response	Minimum weight design
1166	1984
Measurement techniques	Mining equipment
147, 428, 484, 694, 768, 903, 1095, 1107, 1108, 1116, 1150, 1151, 1152, 1153, 1154, 1155, 1213, 1287, 1484, 1614, 1665, 1783, 2114, 2156, 2265, 2382, 2518, 2519, 2534, 2546	143
Measuring instruments	Missiles
218, 221, 222, 1713, 2156, 2264, 2535, 2536, 2537, 2539, 2541, 224, 241, 429, 490, 492, 706, 708, 1128, 1130, 1131, 1818, 1819, 1820, 2081	326, 1013
Mechanical admittance	Mixed element technique
155	1428
Mechanical components	Mobility functions
876, 2104	2178
Mechanical drives	Mobility method
283, 475	2274, 2277
Mechanical impedance	Modal analysis
155, 706, 1994, 2212	109, 197, 227, 231, 383, 390, 418, 499, 540, 686, 747, 758, 783, 905, 906, 1070, 1126, 1268, 1312, 1327, 1369, 1505, 1533, 1612, 1636, 1646, 1670, 1671, 1688, 1690, 1693, 1782, 1789, 1823, 1824, 2049, 2072, 2080, 2117, 2118, 2125, 2127, 2131, 2132, 2133, 2134, 2139, 2141, 2153, 2163, 2166, 2169, 2173, 2178, 2183, 2184, 2190, 2193, 2199, 2201, 2207, 2209, 2211, 2223, 2239, 2241, 2243, 2253, 2256, 2269, 2273, 2279, 2280, 2289, 2296, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2306, 2307, 2309, 2314, 2315, 2317, 2318, 2319, 2320, 2321, 2322, 2324, 2325, 2337, 2345, 2349, 2355, 2360, 2361, 2362, 2364, 2365, 2366, 2367, 2389, 2397, 2402, 2404, 2415, 2439, 2440, 2441, 2445, 2456, 2457, 2458, 2483, 2515, 2516, 2519, 2527, 2528, 2532, 2533, 2544, 2547, 2551, 2566, 2571
Mechanical systems	Modal balancing technique
458, 507, 925	500, 2608
Membranes	Modal confidence method
106, 107, 162, 172, 627, 843, 1052, 1424, 2179, 2213	2545
Metal working	Modal constraint method
542, 1369, 1875, 2129	1058
Metals	Modal control techniques
1638, 1919	51, 1916, 1917, 2567, 1326, 2445
Method of superposition	Modal coupling
1849, 2470	2454
Microcomputers	Modal damping
1423, 1495, 1779, 1852, 2582	322, 610, 1005, 1007, 1008, 1654
Microphones	Modal energy reallocation method
662, 1550	882
Military standards	Modal filters
2593	148
Military vehicles	Modal methods
2289, 2579	710
Milling (machinery)	
2389	
Milling (machining)	
1370, 1874, 2388	
Mindlin theory	
677, 639, 845, 1965	

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Modal models	Moving strips
229, 1671, 1825, 2068	2206
Modal residualization technique	Multi degree of freedom systems
2567	133
Modal strain energy method	Multibeam systems
292, 1101, 1104	2207
Modal superposition method	Multibody systems
509, 1073, 1480, 1660, 1682, 2072, 2136	1145, 1329, 1457, 1619, 2345, 2348, 2351, 2352
Modal synthesis	Multifrequency excitation
709, 777, 1191, 1328, 1822, 1827, 2269, 2297, 2387, 2403,	1147
2404, 2527	Multiphase-step-sine method
Mode acceleration method	2070
1298, 1520	Multiplane balancing techniques
Mode displacement method	2340
1520	Multiple scale method
Mode response on trace method	1346, 1966, 2108
2542	Multiple shakers
Mode shapes	1331
24, 67, 91, 95, 121, 153, 229, 230, 322, 612, 617, 648,	Multipoint excitation techniques
719, 771, 795, 833, 849, 1026, 1064, 1169, 1177, 1191,	244, 1336, 1845, 2161, 2307, 2558, 904
1243, 1283, 1289, 1410, 1411, 1416, 1423, 1424, 1442,	Multireference method
1445, 1468, 1589, 1638, 1665, 1761, 1774, 1930, 1983,	2551
1987, 1988, 2000, 2079, 2088, 2120, 2188, 2213, 2229,	Multistory buildings
2232, 2308, 2310, 2312, 2314, 2368, 2395, 2465, 2542, 2559	15, 104, 288, 289, 290, 546, 549, 550, 753, 761, 762, 956,
Model strain energy method	1520, 1521, 1887, 1890, 2139, 2140, 2141, 2507
1105	Multi-degree-of-freedom systems
Model testing	289, 344, 887, 1459, 1711, 1808, 1845, 2048, 2051, 2055,
273, 304, 361	2093, 2508, 2527
Monitoring techniques	Musical instruments
248, 249, 250, 251, 252, 253, 254, 504, 505, 506, 720, 721,	371, 2458
722, 723, 915, 916, 917, 918, 919, 920, 990, 1143, 1344,	Mykiltstadt method
1495, 1496, 1497, 1498, 1841, 2091, 2341, 2343, 2609	1887
Monitoring	- N -
2342	Natural frequencies
Monte Carlo method	67, 91, 95, 106, 113, 114, 118, 121, 125, 131, 153, 185,
109, 453, 1802, 1847, 1982, 2485	189, 238, 353, 357, 381, 396, 402, 405, 522, 591, 607, 617,
Moorings	624, 633, 639, 648, 771, 824, 833, 844, 846, 849, 970, 977,
1575, 1578, 2148	1026, 1064, 1158, 1191, 1236, 1257, 1280, 1283,
Motor vehicle engines	1289, 1350, 1402, 1410, 1411, 1416, 1417, 1424, 1425,
1705	1428, 1430, 1442, 1443, 1446, 1468, 1556, 1568, 1586,
Motor vehicles	1587, 1589, 1595, 1605, 1616, 1650, 1683, 1739, 1761,
1725, 2187	1774, 1805, 1808, 1858, 1871, 1930, 1978, 1981, 1983,
Mountings	1987, 1988, 1996, 2000, 2021, 2124, 2207, 2213, 2222,
64, 799, 1922	2228, 2232, 2237, 2244, 2246, 2308, 2314, 2318, 2385,
Mounts	2462, 2465, 2477, 2542, 2559, 2564
2405, 2540	Natural modes
Moving loads	1127
14, 409, 555, 616, 702, 747, 769, 1175, 1176, 1602, 1707	Near-field region
	110

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Newmark method
 96, 126, 1581, 1887

Newton-Raphson method
 71, 72

Noise analyzers
 226

Noise barriers
 1623

Noise control
 41, 449, 1204, 1909

Noise generation
 7, 11, 180, 334, 339, 340, 415, 446, 448, 597, 749, 866,
 872, 1300, 1369, 1401, 1456, 1514, 1560, 1769, 1979, 2149,
 2253

Noise measurement
 305, 332, 338, 339, 360, 798, 861, 1213, 1570, 1783, 1911,
 2081, 2412

Noise prediction
 280, 445, 447, 541, 1174, 1214, 1567, 1742, 2388, 2485

Noise reduction
 9, 13, 39, 40, 53, 155, 281, 414, 423, 572, 585, 665, 666,
 748, 752, 862, 999, 1000, 1001, 1168, 1453, 1455, 1541,
 1544, 1617, 1620, 1621, 1622, 1623, 1706, 1725, 1952,
 2127, 2155, 2169, 2258

Noise source identification
 427, 994, 1517, 1784, 2256, 2267, 2460, 2518

Noise tolerance
 333, 581, 1014

Noise transmission
 2156, 2410, 2502

Noncontacting probes
 219

Nondestructive tests
 233, 234, 713, 780, 1132, 1139, 1339, 1607

Nonlinear damping
 35, 1559, 1905

Nonlinear response
 21, 400, 614, 615, 702, 775, 1046, 1593, 1599, 1709, 2145,
 2146, 2255, 2531

Nonlinear springs
 1511

Nonlinear stiffness
 190

Nonlinear systems
 265, 267, 729, 737, 881, 887, 1073, 1313, 1470, 1515,
 1807, 2093, 2099, 2141, 2304, 2353, 2354

Nonlinear theories
 133, 134, 261, 275, 619, 623, 930, 1016, 1042, 1345, 1434,
 1776, 2248, 2355, 2476

Nonproportional damping
 197

Nonsynchronous vibration
 1414

Normal density functions
 462, 1847

Normal mode method
 1304, 1312, 1581, 2330

Normal modes
 96, 176, 440, 441, 516, 649, 673, 826, 868, 933, 1646,
 1830, 2272

Notched structures
 1971

Nozzles
 414, 862, 2248, 2259

Nuclear containment structures
 1193, 1196, 1903

Nuclear explosion effects
 184, 221, 326, 1439, 2041, 2506

Nuclear fuel elements
 781, 782, 918, 988

Nuclear power plants
 28, 29, 300, 458, 756, 757, 758, 778, 803, 804, 806, 808,
 811, 858, 860, 989, 1179, 1196, 1197, 2147, 2398, 2399,
 2428

Nuclear powered ships
 32

Nuclear reaction safety
 989

Nuclear reactor components
 2236, 249, 297, 505, 556, 780, 781, 920, 1074, 1076, 1080,
 1241, 2012, 2143, 2398

Nuclear reactor containment
 28, 1073, 2023

Nuclear reactor safety
 299

Nuclear reactors
 298, 306, 557, 655, 765, 779, 915, 986, 987, 1194, 1198,
 1199, 1536, 1719, 2145, 2146, 2399

Nuclear waste depositories
 671, 782

Nuclear weapons effects
 2463

Abstract
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
---------------	---	---	---	---	---	---	---	---	---	----	----	----

Numerical methods	Parallelepiped bodies											
266, 267, 520, 738, 2106, 2107, 2267, 2356, 2464, 2469, 2484, 2538, 2612	1650, 1998											
- O -												
Oceans	Parameter identification techniques											
1757, 2495	524, 663, 739, 740, 934, 935, 936, 937, 938, 1003, 1004, 1171, 1327, 1504, 1688, 1690, 1693, 1694, 1823, 1913, 1938, 2190, 2282, 2309, 2312, 2319, 2321, 2322, 2324, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2379, 2395, 2406, 2407, 2516, 2517, 2524, 2525, 2528, 2529, 2532, 2545, 2550, 2551, 2613, 830, 1156, 1628											
Off-highway vehicles	Parametric excitation											
2405	1516, 2044, 2050											
Off-shore structures	Parametric resonance											
25, 141, 143, 203, 558, 559, 560, 561, 562, 563, 764, 1200, 1201, 1392, 1573, 1584, 1675, 1720, 1721, 1722, 1723, 1757, 1904, 1906, 2136, 2237, 2335, 2400, 2401	1511, 2200, 2275											
Oil dampers	Parametric response											
1653	735, 2015											
Oil film bearings	Parametric vibrations											
1400, 1706, 1941, 1942, 2116	1518, 192, 1034											
Openings	Particular integral method											
1083	2350											
Opening-containing media	Pasternak foundations											
2026	1065, 1605											
Optical probes	Pavements											
219	554, 769, 1658											
Optimization	Penalty technique											
75, 119, 728, 937, 1031, 1091, 1214, 1228, 1272, 1356, 1373, 1592, 1636, 1857, 1858, 2157, 2175, 2301, 2391, 2494, 2511, 2571	2301											
Optimum control theory	Pendulums											
325, 586, 1091	2057, 2089, 2355											
Optimum design	Penetration											
376, 579, 801, 807, 1021, 1166, 1370, 1689, 1695, 1735, 2135	1637											
Orthotropism	Periodic excitation											
844, 851	16, 87, 100, 463, 880, 889, 1065, 1269, 1290, 1539, 1574, 1608, 1963, 2161, 2523											
Oscillation	Periodic response											
564, 646, 1051, 2148, 2501	266, 615, 733, 805, 1408, 1441, 1739, 1772, 1861, 1930, 2048, 2206, 2273, 2360											
Oscillators	Periodic structures											
680, 891, 1648, 1649, 2096	515, 928, 1412, 1419, 1850, 1851, 2117, 2204, 2274, 2487											
- P -												
Packaging	Personal computers											
1737, 1926	527, 2021, 2577, 2598											
Panels	Perturbation method											
108, 391, 392, 393, 394, 628, 1053, 1141, 1273, 1592, 1615, 1984, 1985, 1986, 2166, 2488	2183											
Paper products	Perturbation theory											
218, 2114	18, 142, 185, 513, 514, 691, 724, 725, 1347, 1540, 1866, 1961, 2056, 2296, 2302, 2489, 2562											
Parabolic bodies	Phase methods											
1045	2395, 2524											
Abstract	Phase resonance method											
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615	805, 2305											
Volume 18												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Phase separation method	Pneumatic dampers
1830, 2305	348
Photoelastic analysis	Pneumatic isolators
213, 1118	589, 1923
Photographic techniques	Pneumatic lines
568, 1765	1071
Piers	Pneumatic springs
1519	349, 589, 1022, 1238
Piezoceramics	Pneumatic tires
194	2180, 2181
Piezoelectric transducers	Pneumatic tools
487, 488	1017
Pile driving	Point source excitation
20, 1386	434, 1790, 2007, 2466, 2474
Pile structures	Poisson's ratio
19, 21, 903, 963, 1202, 1384, 1385	1965, 2222
Piles	Polymers
22	1473, 2061
Pipe whip restraints	Polyreference method
1080	2545
Pipe whip	Polyurethane resins
858, 1638, 2012, 2241	2171
Pipelines	Porous materials
146, 249, 418, 419, 420, 653, 656, 859, 860, 1070, 1072, 1073, 1074, 1075, 1076, 1077, 1201, 1293, 1294, 1295, 1392, 1447, 1609, 1610, 1782, 1794, 2015, 2020, 2021, 2236, 2237, 2239, 2240, 2241, 2243, 2244, 2338	434, 442, 707, 1302, 1941, 1942, 1947, 2260
Pipes	Positioning devices
143, 144, 657, 780, 857, 858, 1078, 1079, 1611, 1829, 2013, 2014, 2016, 2017, 2238, 2242, 2479, 2481	681
Pistons	Power plants (facilities)
452, 947	2341
Pivoted pad bearings	Power plants
1949	7, 10, 990, 1113, 1535
Plane wave approximation	Power spectra
135	453
Planet gears	Power spectral density
600, 1402, 1569	1847, 463, 540, 1150, 1151, 1152, 1153, 1154, 1155, 2515
Plates	Power transmission systems
46, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 162, 172, 395, 396, 398, 406, 407, 409, 545, 629, 631, 632, 633, 634, 637, 638, 704, 705, 844, 845, 847, 1054, 1055, 1274, 1275, 1276, 1277, 1278, 1279, 1286, 1287, 1300, 1310, 1324, 1372, 1405, 1416, 1419, 1424, 1425, 1426, 1427, 1428, 1429, 1430, 1431, 1432, 1474, 1593, 1594, 1595, 1615, 1643, 1710, 1770, 1772, 1773, 1774, 1777, 1779, 1988, 1989, 1990, 1991, 1998, 2024, 2214, 2216, 2217, 2218, 2221, 2223, 2224, 2225, 2283, 2418, 2459, 2460, 2461, 2462, 2463, 2464, 2470, 2510	282, 1368, 1513, 1566, 1750
	Prediction techniques
	480, 1115, 2092
	Presses
	281, 748, 1174
	Prestressed concrete
	561, 618, 1265, 1659, 1707, 1885
	Prestressed structures
	406

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1895 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Prismatic bodies	Railroad cars
141, 377, 849, 1093	1724, 2580
Probability density function	Railroad tracks
263, 350, 462, 558, 2093	555
Probability theory	Railroad trains
294, 2039	584, 785, 787, 1238, 1538, 2578
Proceedings	Railroads
1620	1190
Projectile penetration	Rails
874	1188, 1189
Propellant tanks	Railway wheels
2235	718, 813, 1343
Propeller blades	Rail-vehicle interaction
68, 359, 360, 361, 362, 363, 364, 365, 393, 816, 942, 1215, 1224, 1559, 1560, 1742, 1743, 1930	784, 1538
Propeller noise	Rail-wheel interaction
2030	776, 784, 785, 1188, 1189, 1539
Propellers	Raleigh-Ritz method
11, 422, 1225, 1226, 1227, 1784	771, 1057
Proximity probes	Random decrement technique
1817, 2521, 2534	99, 2088
Pseudodynamic testing method	Random excitation
1460, 1673	33, 34, 109, 130, 270, 367, 464, 552, 699, 1466, 1469, 1646, 1992, 2051, 2063, 2097, 2161, 2447, 2512, 2600
Pulse combustion devices	Random parameters
174	735, 1348, 2051
Pulse excitation	Random response
62, 1047, 1271, 1484, 1640, 1897, 2191, 2330, 2463, 2474, 2482	827, 1656, 1771, 1985, 2043, 2101, 2357, 2360, 2515, 2583
Pumps	Random tests
9, 10, 920, 947, 1165, 1241, 1407, 2126, 2384	2584
Perturbation theory	Random vibration tests
2100	2601
Pyrotechnic shock environment	Random vibration
495, 2596	412, 454, 529, 714, 715, 892, 1312, 1378, 1388, 1459, 1803, 1804, 1805, 1808, 1865, 1982, 2010, 2049, 2050, 2096, 2157, 2276, 2304, 2369, 2493, 2507, 2581, 2588, 2590
- Q -	Rational fraction polynomials
Quartz crystals	2308
220, 1820, 2077, 2329	Rayleigh method
Quartz	728, 2094
1285	Rayleigh-Ritz method
- R -	124, 384, 399, 509, 846, 1177, 1598, 2121, 2222, 2223, 2467
Radioactive materials	Reciprocating compressors
988	517, 1307, 2021
Railroad bridges	Reciprocating engines
1176, 1519, 1707	1367, 1493

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Reciprocating machinery	Resonant response
749	357, 436, 647, 985, 1402, 1472, 1602, 1759, 1933, 2099, 2202, 2227, 2381, 2486
Recording instruments	Resonators
224, 1129	220, 1820, 2077, 2329
Rectangular bars	Response spectra
826	23, 940, 1381, 1682, 2067
Rectangular beams	Response spectral density
89, 1586	2130
Rectangular bodies	Restoring factors
2482	1905
Rectangular panels	Retaining walls
1987	151
Rectangular plates	Reverberation chambers
123, 124, 125, 126, 127, 128, 129, 130, 397, 400, 408, 635, 636, 846, 848, 1056, 1057, 1058, 1285, 1285, 1433, 1434, 1596, 1597, 1598, 1599, 1769, 1771, 1993, 1994, 1995, 1996, 1997, 2222, 2226, 2463, 2466, 2467, 2468, 2469, 2534, 2548	2316
Recursive methods	Reviews
1845	573, 587, 604, 619, 672, 711, 721, 992, 1130, 1239, 1321, 1393, 1456, 1498, 1538, 1679, 1804, 1857, 1858, 1974, 2219
Reduction methods	Ribs (supports)
90, 514, 926, 927, 1500	640, 641
Reentry vehicles	Ride dynamics
327	302, 777
Reinforced concrete	Rigid body modes
105, 149, 547, 548, 609, 613, 661, 756, 760, 839, 939, 959, 960, 961, 1179, 1373, 1376, 1379, 1461, 1594, 1710, 1711, 1889, 1903, 1972, 2026, 2085, 2141	2317, 2557, 2561
Reinforced structures	Rigid foundations
411, 1078	23, 552, 2384
Reissner method	Rigid plastic properties
2002	1640
Reliability	Rings
294, 389, 460, 493, 494, 1719	413, 650, 1445, 1446, 2181, 2213, 2451
Residual compliance matrix	Ritz method
2074	113, 1433, 1467, 1589, 1595, 1998, 2226
Resonance bar techniques	Ritz vectors
1133	1332, 1353
Resonance pass through	Ritz-Galerkin method
1809	1049
Resonance tests	Riveted joints
198, 1729	1036
Resonant column tests	Rivets/joints
966, 967	1607
Resonant frequencies	Road roughness
273, 307, 392, 652, 888, 1285, 1316, 1335, 1777, 2229	296, 334, 777, 2149, 2405
Abstract	Road-vehicle interaction
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615	1178
Volume 18	Robots
Issue: 1 2 3 4 5 6 7 8 9 10 11 12	821, 822, 1880, 1969, 2277, 2355

Rock foundations	R-function method
1180, 1717	1426
Rocket engines	- S -
52	
Rocking	Sand
23	769, 912, 964, 1474, 1529
Rocks	Sandwich panels
1181, 1548, 1549, 1686	109
Rods	Sandwich structures
374, 375, 605, 706, 918, 1964, 1965, 2199, 2200	120, 392, 398, 629, 1279, 1615, 1656, 2166, 2220, 2472
Roller bearings	Scaling
1157, 1253, 1676, 1746, 1936	1791, 2085, 2602
Rolling contact bearings	Screening
73, 243, 244, 254, 723, 1172, 1344, 1496, 2609	715, 2212, 2492, 2493
Rolling friction	Seals
899, 902	84, 85, 901, 1037, 1260, 1407, 1408, 1572, 1573, 1752, 1753, 1754, 1755, 1961, 1962, 2192, 2451, 2452, 2453
Rolling motion	Search techniques
34, 35	1848
Roofs	Seismic analysis
866, 1410	295, 297, 389, 420, 553, 774, 964, 982, 983, 987, 1067, 1184, 1187, 1241, 1379, 1382, 1389, 1391, 1525, 1526, 1633, 1686, 1884
Rooms	Seismic design
669, 2485	15, 18, 151, 454, 547, 548, 661, 759, 778, 807, 808, 842, 893, 939, 940, 961, 979, 1077, 1185, 1240, 1373, 1376, 1381, 1708, 1859, 1889, 2109, 2110, 2429
Rotating machinery	Seismic excitation
504, 540, 914, 1166, 1342, 1865, 1937, 2120, 2170, 2369, 2607, 2608	16, 23, 65, 149, 354, 552, 764, 853, 958, 967, 1088, 1180, 1186, 1382, 1387, 1388, 1459, 1635, 1865, 1903, 2023, 2039, 2105, 2144, 2233, 2331
Rotating structures	Seismic isolation
12, 374, 888, 1446, 2121, 2122, 2377, 2477	557, 587, 685, 803, 804, 805, 806, 809, 810, 811, 812, 1241, 1374, 1522, 2424, 2425, 2426, 2430, 2431
Rotational degrees of freedom	Seismic response spectra
2300	453, 865, 939, 1298, 1525, 1526, 1527, 1794, 2109
Rotational response	Seismic response
49, 730	28, 29, 79, 105, 150, 152, 153, 185, 255, 285, 287, 288, 289, 298, 407, 412, 424, 455, 457, 492, 546, 549, 551, 638, 760, 761, 762, 766, 773, 775, 782, 839, 840, 852, 860, 878, 933, 939, 960, 962, 963, 989, 1074, 1075, 1087, 1177, 1193, 1197, 1198, 1199, 1203, 1295, 1372, 1376, 1380, 1383, 1390, 1438, 1460, 1461, 1520, 1522, 1533, 1534, 1634, 1710, 1715, 1716, 1718, 1719, 1766, 1781, 1845, 1882, 1883, 1888, 1890, 1972, 2006, 2015, 2085, 2140, 2141, 2142, 2143, 2147, 2239, 2369, 2394, 2507, 2508
Rotatory compressors	Seismic tests
2604	236, 712, 1022, 1135, 1179, 1196, 1536, 1673, 1793, 2023, 2398
Rotatory inertia effects	Seismic waves
119, 130, 608, 621, 634, 639, 650, 1056, 1200, 1259, 1300, 1328, 1362, 1425, 1931, 1960, 1970, 1973, 2206, 2210, 2461	186, 1352
Rotor blades (turbomachinery)	
351, 352, 403, 1027	
Rotor blades	
817, 1740	
Rotors	
2, 5, 272, 274, 275, 276, 501, 535, 536, 537, 538, 539, 540, 743, 744, 944, 1037, 1125, 1160, 1162, 1359, 1360, 1361, 1362, 1400, 1511, 1512, 1515, 1697, 1698, 1749, 1838, 1861, 1862, 1866, 1867, 1868, 1870, 1871, 1925, 2090, 2115, 2340, 2370, 2371, 2372, 2373, 2374	

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Self-excited vibrations	Shock absorbers
192, 1225, 2044	799, 1236, 1555
Semiactive vibration	Shock absorption
1239	66
Sensitivity analysis	Shock excitation
1867, 2298	2128
Servomechanisms	Shock isolation
2385	326, 683, 2173
Shafts	Shock isolators
3, 214, 277, 532, 533, 943, 1158, 1159, 1161, 1163, 1363, 1364, 1506, 1507, 1513, 1583, 1696, 1697, 1738, 1755, 1839, 1863, 1864, 1869, 2089, 2117, 2118, 2119, 2337, 2376, 2377, 2378, 2379, 2380, 2381, 2382	348, 589, 1636
Shakedown theorem	Shock resistant design
388	1465
Shakers	Shock response spectra
910, 975, 1022, 1340, 1831, 2332, 2575, 2576, 2590, 2601	1465, 1870
Shear modulus	Shock response
470, 768, 909, 2114	135, 394, 708, 1206, 1724, 1857
Shear strength	Shock tests
613	17, 459, 492, 1491, 1831, 1832, 2592, 2597, 2598, 2600
Shear vibration	Shock tube testing
1650	875
Shear waves	Shock wave attenuation
1089, 1183, 1447, 1619	1306, 1307, 2037
Sheer strength	Shock wave propagation
661	450, 674, 879, 1089, 1798, 2484
Shells of revolution	Shock waves
1068, 1999	117, 183, 1244, 1311, 1463, 1464, 1499, 1637, 1642, 1797, 1799, 1800, 1801, 1802, 2042, 2268
Shells	Shock wave-boundary layer interaction
133, 134, 135, 141, 409, 647, 849, 963, 1067, 1438, 1439, 1440, 1447, 1594, 1601, 1602, 1643, 1781, 1828, 1902, 2000, 2227, 2228, 2247, 2476	660, 1090
Ship anchors	Shrouds
1575	422, 1557, 1932, 1933
Ship hulls	Siftened plates
1209, 2406	1063
Ship noise	Signal processing techniques
1632	485, 722, 723, 905, 1140, 1486, 1487, 1488, 1494, 1953, 2028, 2543, 2549
Shipboard equipment response	Signal processing
32, 1816	2336
Shipping containers	Signature analysis
671	1676, 1816, 2336, 2497, 2558, 2609
Ships	Silencers
33, 34, 35, 36, 203, 306, 308, 394, 563, 566, 993, 1207, 1208, 1210, 1211, 1212, 1393, 1495, 1540, 2150, 2151	57
	Simulation
	453, 949, 1143, 1610, 1876, 1935, 2035, 2356, 2503, 2508, 2579, 2583, 2589, 2602

Abstract
Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Sine-dwell technique	Sound attenuation
1726	2024
Single degree of freedom systems	Sound generation
1088, 1147, 1346, 1459, 1472	8, 1872, 2029, 2271
Single point excitation technique	Sound insertion noise
198, 1726, 2307, 2414	438
Sinusoidal excitation	Sound level meters
635, 1395, 2282	177, 490, 1669
Skew plates	Sound measurement
402, 630, 1778, 2220	171, 2033, 2034, 2316
Slabs	Sound power levels
609, 613, 1186, 1319	171, 1086, 2519
Slamming	Sound pressure levels
788	1625
Slider crank mechanisms	Sound pressure
1751	1454
Sliding bearings	Sound propagation
1838	160, 258, 259
Sliding friction	Sound transmission loss
242	159, 164, 425, 444
Sliding supports	Sound transmission
1522	140, 391, 628, 631, 1523, 2392
Sling loads	Sound waves
1230	92, 93, 107, 157, 161, 162, 169, 170, 172, 173, 175, 176, 178, 179, 234, 391, 395, 421, 423, 428, 429, 430, 432, 433, 434, 435, 436, 439, 441, 659, 667, 668, 867, 868, 869, 870, 871, 1082, 1083, 1084, 1085, 1275, 1296, 1301, 1302, 1303, 1304, 1403, 1421, 1435, 1448, 1449, 1451, 1452, 1463, 1514, 1558, 1601, 1627, 1629, 1630, 1632, 1661, 1779, 1780, 1787, 1788, 1789, 1790, 1791, 1792, 2001, 2007, 2018, 2021, 2030, 2031, 2032, 2036, 2106, 2248, 2249, 2251, 2252, 2261, 2263, 2264, 2266, 2495, 2496, 2498, 2500, 2566
Sloshing	Sound
139, 297, 307, 557, 1316, 1317, 1318, 1734, 1806, 1918, 2006	797
Snow	Space shuttles
181	52, 232, 329, 330, 331, 332, 1007, 2419, 2421, 2574
Soils	Space stations
20, 26, 294, 442, 443, 456, 525, 674, 766, 768, 909, 964, 966, 967, 968, 1184, 1899, 1900, 1901	1234, 2165
Soil-foundation interaction	Spacecraft components
965, 969, 1180, 1711, 2037, 2170, 2435	687, 2165, 2166, 2167, 2553
Soil-structure interaction	Spacecraft equipment response
19, 22, 293, 350, 551, 560, 757, 765, 767, 769, 871, 963, 971, 1043, 1044, 1183, 1384, 1388, 1529, 1530, 1531, 1532, 1712, 1713, 1714, 1719, 1892, 1893, 1896, 1897, 1898, 2005, 2041, 2143, 2394, 2508	324, 686
Solar energy	Spacecraft instrumentation responses
1547	1012, 1011
Sommerfeld number	Spacecraft platforms
1254	50, 411, 580, 1011
Sonic boom	
2035	
Sonograms	
643	

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1895 1896-1860 1861-2114 2115-2388 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Stress amplification factors
2290

Stress analysis
2188, 2521

Stress intensity factors
2098, 2217

Stress waves
1124, 1499, 1639, 1777, 1799

Strings
93, 371, 1574, 1963, 2194

Strip method
1183, 1778

Strips
1579

Structural damping
1403

Structural members
212, 267, 424, 474, 543, 710, 863, 864, 1049, 1079, 2486, 2487

Structural modification techniques
30, 227, 228, 313, 534, 566, 666, 817, 906, 1091, 1127, 1353, 1687, 1694, 1695, 2094, 2172, 2209, 2234, 2244, 2296, 2298, 2299, 2300, 2301, 2391, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2603

Structural response
1308, 1520, 1533, 2095

Structural synthesis
264, 1356

Structure borne noise
281, 573, 574, 1287, 1543, 1619, 2165

Structure borne vibration
631

Structure-foundation interaction
65, 1463, 1717

Structure-ground interaction
1894, 1895

Struts
1210

Subharmonic oscillations
864, 512, 922, 1574, 2045, 2376

Submarine hulls
1910

Submarines
32, 1577

Submerged structures
93, 99, 110, 135, 140, 141, 143, 183, 375, 380, 402, 467, 620, 628, 633, 682, 717, 1291, 1313, 1314, 1315, 1759, 1780, 2054, 2202, 2292, 2295, 2400

Subspace method
2349, 2530

Substructuring methods
264, 320, 511, 906, 1332, 1333, 1460, 1718, 2073, 2120, 2211, 2277, 2288, 2297, 2403, 2416

Subsynchronous vibration
745, 943, 1161, 1366, 1703, 2381

Successive transformation method
2288

Sum and difference frequencies
1574, 1837

Summation of forces method
1727

Superharmonic vibrations
2045

Supports
24, 1442, 1595, 1669, 1737, 1925, 1937, 1969, 1975, 2244, 2378, 2507

Surface effect machines
304, 306, 364

Surface roughness
14, 296, 1537, 1611, 1645, 1790, 1907

Suspended structures
152

Suspension bridges
951, 952, 1175, 2455

Suspension systems (vehicles)
60, 61, 349, 586, 802, 1236, 1238, 1554, 2174, 2175, 2176, 2180, 2437

Swept sine wave excitation
1774, 1829, 2581, 2584

Synchronous motors
1358

Synchronous vibration
1, 943

Synchrophasing method
2155

System analysis
2347

System identification techniques
269, 308, 503, 521, 522, 323, 524, 760, 933, 939, 1326, 1335, 1692, 1856, 1882, 2338, 2368

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Spacecraft	Statistical energy methods
49, 51, 228, 292, 311, 312, 320, 321, 322, 323, 325, 328,	885, 1354, 2263
469, 730, 800, 820, 1003, 1004, 1005, 1006, 1008, 1009,	
1010, 1102, 1104, 1132, 1233, 1266, 1394, 1406, 1546,	
1547, 1734, 1735, 1767, 1806, 1828, 1914, 1915, 1916,	
1917, 1918, 1919, 2160, 2161, 2162, 2163, 2164, 2313,	
2339, 2415, 2416, 2417, 2418, 2422, 2574	
Specifications	Steam turbines
2592	745, 915, 1030, 2371
Spectrum analysis	Steel
226, 250, 1381, 1489, 1517, 1782, 1812, 2067, 2149, 2189,	28, 199, 200, 201, 202, 203, 204, 205, 370, 480, 506, 544,
2315, 2455, 2489	622, 625, 693, 1117, 1195, 1373, 1461, 1889, 1971, 2110
Spheres	Step functions
273, 2294	1597
Spherical shells	Step relaxation method
156, 410, 646, 682, 851, 1065, 1066, 1442, 1604, 1605,	1826
2001, 2002, 2219	
Spindles	Stepped-sine excitation
1157, 1172	2311
Spline technique	Stick-slip excitation
384, 1778, 1848	1407
Spoilers	Stick-slip response
880	883, 1092, 1749
Spokes	Stiffened plates
1446	401, 405, 1992, 2219
Spring constants	Stiffened shells
963, 1565	648
Springs	Stiffeners
657, 812, 1966, 2093, 2177, 2438	1421
Spring-supported foundations	Stiffness coefficients
980, 981	20, 84, 85, 550, 593, 693, 934, 935, 936, 1254, 1319, 1396,
Spur gears	1543, 1573, 1691, 1748, 1863, 1940, 1944, 1947, 2192,
1566, 1567, 1568, 1951, 2446	2199, 2371, 2385, 2391, 2453, 2511
Squeeze-film bearings	Stiffness effects
593, 1398, 1938, 1964	277, 1542, 1655
Squeeze-film dampers	Stiffness matrices
196, 693, 1322, 1323, 1398, 1652, 2052, 2053, 2225	1156, 1420, 1683, 1692, 1850, 1851, 1855, 2326
Stability	Stiffness
263, 316, 362, 513, 535, 593, 626, 925, 1269, 1408, 1512,	2342
1680, 1807, 1905, 1939, 1941, 1942, 2116, 2119, 2131	
Stalling	Stochastic processes
1508, 1509	18, 289, 350, 386, 698, 918, 1345, 1380, 1635, 1685, 1854,
Standards and codes	1856, 1982, 2050, 2097, 2130, 2145, 2146, 2162, 2600
448, 972, 1227, 1367, 1889, 2333, 2540, 2594	
State space approach	Storage tanks
231	412, 852, 853, 1918, 2005, 2006, 2478
Statistical analysis	Strain gages
558, 1088, 1305, 1452, 1628, 1846, 2039, 2124, 2357	704, 705, 2082
	Strains
	2303, 2597

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 19

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

- T -

Takeoff
314

Tanker ships
307

Tanks (containers)
139

Taylor series
523, 2051

Temperature effects
125, 194, 470, 479, 630, 633, 675, 715, 866, 1059, 1061, 1062, 1076, 1119, 1321

Tennis rackets
2281

Test equipment
901, 910, 969, 1189, 1832, 2506

Test facilities
318, 444, 476, 477, 531, 716, 792, 875, 908, 1337, 1338, 1340, 1491, 2084, 2331, 2332, 2419, 2421, 2499, 2520, 2548, 2573, 2574, 2575, 2580, 2582, 2588, 2601

Test models
912, 2313

Test stands
1834

Testing
911

Testing instrumentation
497, 2452, 2586

Testing techniques
42, 232, 245, 331, 493, 494, 495, 496, 498, 712, 714, 764, 909, 969, 1076, 1110, 1132, 1134, 1135, 1341, 1490, 1699, 1700, 1831, 1833, 2069, 2083, 2411, 2452, 2492, 2493, 2522, 2523, 2576, 2578, 2579, 2581, 2583, 2585, 2587, 2594, 2598, 2599

Textile looms
1023, 1515, 1958

Textile spindles
837

Textiles
941

Thermal damping
687, 1321

Thermoelasticity
235, 1100

Three-dimensional problems
655

Thrust bearings
818

Tiles
232, 1286

Tilt pad bearings
1254, 1563, 1948

Time dependent parameters
970

Time domain method
159, 164, 264, 322, 323, 385, 435, 485, 499, 530, 867, 953, 986, 1210, 1387, 1476, 1484, 1485, 1532, 1663, 1666, 1685, 1688, 1690, 1742, 1823, 1835, 2049, 2088, 2303, 2304, 2306, 2307, 2347, 2360, 2361, 2364, 2365, 2389, 2395, 2515, 2517, 2528, 2532

Time integration method
1144

Time series analysis method
223, 1171, 2309

Time shift frequency domain
2321

Time-dependent parameters
1296, 1848

Timoshenko theory
91, 377, 381, 383, 413, 611, 612, 613, 632, 827, 831, 1418, 1419, 1583, 1586, 1871, 1973, 1976, 1981, 2193, 2479

Timoshenko
2380

Tires
302, 1026, 2179, 2439, 2476

Tire-wheel interaction
590, 2180, 2181

Titanium
1142

Toroidal shells
136, 137, 1289, 2007

Torque
274, 947, 1582, 2382

Torsional excitation
3

Torsional response
23, 378, 753, 755, 789, 829, 942, 957, 958, 1255, 1634, 1924

Torsional vibrations
12, 277, 282, 369, 500, 533, 750, 944, 1164, 1358, 1359, 1363, 1506, 1507, 1551, 1696, 2108, 2118, 2120, 2207, 2386, 2448

Towed bodies
1409

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Towed systems	Triangular bodies
1540, 2151, 2432	2470
Towers	Truck tires
291, 292, 763, 764, 2393	390
Track roughness	Trucks
776	1192, 1193, 1236, 1928, 2403, 2404
Tracked vehicles	Truncation
2174, 2437	1694
Tractors	Trusses
777, 1191	623, 841, 1418, 1768
Traffic noise	Tube arrays
53, 177, 334, 335, 445, 1620, 1783, 1920	147, 300, 415, 438, 632, 653, 654, 1069, 1290, 1291, 1292, 2008, 2009, 2010, 2011, 2480
Traffic sign structures	Tubes
1590, 1591	80, 145, 416, 417, 611, 651, 854, 855, 856, 1474, 1608, 2016, 2018, 2143, 2245, 2246, 2247, 2479
Traffic-induced vibrations	Tuned frequencies
335, 584	2417
Transducers	Tuning
492, 1483, 2338	230, 973, 1029, 1031, 1932, 1935, 2275, 2375
Transfer functions	Tunnels
662, 1242, 2347, 2366, 2552	770
Transfer matrix method	Turbine blades
21, 144, 824, 1072, 1868, 2177, 2229, 2344	67, 353, 354, 355, 356, 476, 592, 1028, 1030, 1244, 1245, 1600, 1931, 2441, 2442
Transformation techniques	Turbine components
1348	2290
Transformers	Turbine engines
2080	746, 1113
Transient analysis	Turbine rotors
510, 1686, 1860	1249
Transient excitation	Turbines
1144, 1490, 1594, 2152	6, 502, 2125
Transient response	Turbofan engines
323, 380, 419, 467, 532, 835, 1281, 1293, 1639, 1681, 2043, 2194, 2254	180, 945
Transient vibrations	Turbogenerators
1483, 1925, 2115	978, 979, 1051, 2169
Translational inertia effects	Turbomachinery
2210	5, 977, 980, 981, 1165, 1836, 2375, 2604
Translational response	Turbulence
49, 374, 730, 1261, 1367	98, 173, 354, 358, 365, 577, 578, 660, 677, 793, 956, 1069, 1082, 1201, 1456, 1565, 1745, 1961, 2010, 2053, 2230
Transmission lines	Two degree of freedom systems
604, 1070, 1071, 1610, 2195, 2278, 2287	386
Transportation effects	Two microphone technique
321, 988, 1926	994, 1086, 1614
Transverse shear deformation effects	
114, 118, 119, 130, 608, 612, 621, 634, 639, 650, 1056, 1200, 1300, 1362, 1425, 1931, 1973, 2206, 2461	

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

- U -

Ultrasonic techniques
225, 240, 245, 338, 1142, 1339, 1440, 1817

Ultrasonic vibrations
2538

Unbalanced mass response
64, 538, 944, 1160, 1254, 1511, 1868, 1869, 2116, 2444

Uncoupling technique
2526

Undamped structures
2273

Underground explosions
221, 2506

Underground structures
326, 420, 968, 1183, 1185, 1384, 1447, 1713, 2015, 2041, 2142, 2143

Underwater explosions
117, 401, 1063, 1207

Underwater pipelines
658

Underwater shock waves
451, 877, 1063

Underwater sound
157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 437, 438, 439, 440, 441, 869, 1085, 1304, 1305, 1452, 1629, 1630, 1631, 1632, 1788, 2033, 2034, 2036

Underwater structures
100, 1202, 1203, 1262, 1422, 1758, 2237

Universal joints
1864

- V -

Valves
2092

Van der Pol method
192, 930, 931, 1649, 2044

Vanes
358

Variable cross section
120, 125, 126, 372, 380, 396, 399, 533, 539, 702, 847, 1045, 1203, 1264, 1274, 1281, 1282, 1283, 1420, 1436, 1437, 1583, 1776, 1970, 1974, 1976, 2000, 2014, 2232, 2469, 2484

Variable material properties
2201, 2343

Variable speed drives
750

Variational methods
874, 1470, 2104

Velocity measurement
241

Velocity
2357

Vibration absorption (materials)
801, 1551, 666

Vibration analysers
914

Vibration analysis
1735

Vibration control
4, 13, 69, 154, 220, 228, 319, 344, 345, 422, 583, 658, 681, 737, 745, 817, 882, 894, 941, 946, 1004, 1091, 1158, 1209, 1226, 1229, 1239, 1258, 1326, 1394, 1506, 1547, 1677, 1725, 1732, 1873, 1915, 1927, 2169, 2253, 2400, 2418, 2433, 2434, 2576

Vibration dampers
278, 1113

Vibration damping
324, 468, 666, 746, 820, 1006, 1011, 1012, 1098, 1161, 1168, 1235, 1273, 1321, 2057, 2061

Vibration detectors
2078, 2087

Vibration excitation
342, 1015, 1235, 2423, 2450

Vibration isolation
537, 588, 683, 980, 1921, 2170, 2173

Vibration isolators
58, 59, 347, 732, 973, 1019, 1020, 1021, 1022, 1023, 1550, 1736, 1922, 2055, 2168, 2435

Vibration measurement
218, 332, 484, 504, 704, 705, 1132, 1758, 1818, 1820, 1821, 1885, 2374

Vibration meters
1819

Vibration prediction
403

Vibration probes
709

Vibration response spectra
643

Vibration response
38, 54, 76, 190, 194, 1017, 1276, 1320, 1429, 1437, 1778, 1857, 1931, 1935, 1970, 1980, 1998, 1999, 2107, 2179, 2220

Vibration severity
943

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1st, 8 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Vibration signatures	Viscous friction
1368, 2336, 2609	2037
Vibration tests	Viscous medium
235, 306, 714, 908, 911, 969, 1134, 1180, 1218, 1243, 1490, 1726, 1774, 2073, 2331, 2408, 2411, 2414, 2491, 2523, 2543, 2575, 2576, 2577, 2579, 2581, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2595, 2597	1313
Vibration tolerance	Vlasov theory
1014	377
Vibration transfer	Vortex amplifiers
640, 641, 1078, 1252, 1992	1094, 1095
Vibrators	Vortex shedding
1371	8, 68, 543, 677, 1224, 1267, 1288, 1588, 1647, 1769, 2024
Vibratory techniques	Vortex-induced excitation
542, 1607, 2114, 2212, 2615	1093, 1558
Vibratory tools	Vortex-induced vibration
27, 341, 1548, 1549	97, 359, 816, 834, 1262, 1376, 1743
Vibrometer	Vulnerability
2328	1206
Vibro-impact systems	- W -
2269	Walls
Viscosity effects	69, 149, 150, 444, 661, 1372, 2025, 2026, 2261, 2488
795	Warping
Viscoelastic core-containing media	12
109, 392	Water hammer
Viscoelastic damping	2004
131, 292, 469, 470, 686, 690, 831, 832, 893, 996, 1002, 1104, 1105, 1106, 1111, 1277, 1404, 1473, 1476, 1655, 1656, 1775, 2003, 2286	Water waves
Viscoelastic foundations	1722, 1906, 1910, 2148, 2150
635	Water
Viscoelastic media	2478
186, 966, 1795	Wave attenuation
Viscoelastic properties	173, 436, 441, 1412, 1452
2119, 115, 145, 409, 1035, 1078, 1079, 1149, 1714, 1866, 2294	Wave diffraction
Viscoelasticity	433, 435, 1083, 1311, 1910
1148	Wave dispersion
Viscoelastic-core-containing media	831
1655	Wave energy
Viscoplastic properties	2150
1482	Wave equation
Viscosity effects	1386, 2014
1293	Wave forces
Viscous damping	34, 36, 310, 562, 658, 788, 1202, 1211, 1212, 1314, 1315, 1393, 2400, 2401
471, 605, 610, 615, 685, 812, 1007, 1049, 1101, 1102, 1312, 1416, 1418, 1475, 1551, 1671, 2055, 2068, 2298, 2439	Wave generation
	1082, 1405
	Wave propagation
	83, 101, 116, 146, 157, 163, 165, 166, 169, 176, 178, 179, 186, 263, 268, 382, 421, 423, 432, 440, 659, 667, 731, 797, 854, 868, 869, 871, 877, 921, 1084, 1085, 1124, 1128,

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Wave propagation (cont'd.)
 1268, 1304, 1311, 1351, 1419, 1448, 1449, 1451, 1458,
 1499, 1601, 1606, 1612, 1627, 1629, 1630, 1632, 1639,
 1642, 1661, 1662, 1760, 1790, 1791, 1799, 1894, 1895,
 1965, 1991, 2001, 2016, 2018, 2066, 2101, 2197, 2203,
 2204, 2248, 2249, 2251, 2252, 2264, 2266, 2274, 2310,
 2330, 2483, 2487, 2495, 2496, 2500, 2513

Wave radiation
 92, 93, 107, 429, 1275, 1421, 1514, 1558, 1780, 1789,
 1792, 1910, 2007, 2030, 2263, 2498, 2566

Wave reflection
 77, 430, 718, 854, 1096, 1302, 1800, 1802

Wave scattering
 161, 162, 172, 175, 668, 717, 867, 870, 1301, 1303, 1435,
 1452, 2031, 2036, 2292, 2295, 2514

Wave transmission
 77, 434, 1083, 1096, 1779, 2032, 2261

Waveguide absorbers
 894

Waveguide analysis
 2483

Waveguides
 2266

Weapons systems
 64

Wear
 1835

Wedges
 433, 1802

Weighted residual technique
 2358, 2527

Welded joints
 80, 81, 82, 245, 545, 602, 1607

Wheelsets
 813

Whirling
 1, 276, 1163, 1365, 1698, 1867, 1942, 2185, 2378

Wind induced excitation
 1644

Wind tunnel testing
 491, 642, 792, 1090, 1125, 1244, 1267, 1562, 1626, 1912,
 2158

Wind tunnels
 2030

Wind turbines
 340, 354, 667, 1243, 1704, 2124, 2393

Windows
 1309, 1310

Wind-induced excitation
 42, 290, 291, 354, 437, 543, 565, 576, 579, 642, 677, 753,
 754, 755, 763, 935, 956, 957, 1175, 1211, 1222, 1378,
 1438, 1472, 1528, 1791, 2095, 2139, 2157, 2195, 2271, 2393

Wing stores
 318, 1730, 2408

Winkler foundations
 1057, 1065

Wire cloth
 1410

Wire
 1117, 1498, 1674

Wires
 1038, 1759

Wood
 373, 425, 2025

Woodworking machines
 2440

Work pieces
 1369

- Y -

Young modulus
 2114

- Z -

Z-transform
 1485, 1666

Abstract

Numbers: 1-271 272-531 532-742 743-942 943-1156 1157-1357 1358-1505 1506-1695 1696-1860 1861-2114 2115-2368 2369-2615

Volume 18

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

CALENDAR

1987

JANUARY

12-15 AIAA 25th Aerospace Sciences Meeting, Reno, NV

FEBRUARY

24-28 SAE International Congress "Excellence in Engineering," Cobo Hall, Detroit, MI (SAE Engrg. Activities Div., 400 Commonwealth Drive, Warrendale, PA 15096)

MARCH

10-12 Power Plant Pumps Symposium [Electric Power Research Institute], New Orleans, LA (Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto CA 94304)

6-9 56th International Modal Analysis Conference [Union College and Imperial College of Science], London, England (IMAC, Union College, Graduate and Continuing Studies, Wells House -- 1 Union Ave., Schenectady, NY 12308)

6-8 AIAA 28th Structures, Structural Dynamics and Materials Conference, Monterey, CA

9-10 AIAA Dynamics Specialist Conference, Monterey, CA

APRIL

13-16 IEEE Intl. Conf. on Acoustics, Speech, and Signal Processing, Dallas, TX

13-16 IUTAM Symp. on Advanced Boundary Element Methods, San Antonio, TX

28-30 1987 SAB Noise and Vibration Conference, Traverse City, Michigan (SAE, 400 Commonwealth Drive, Warrendale, PA 15086 (412) 776-4841)

MAY

3-8 33rd International Instrumentation Symposium [Aerospace Industries and Test Measurement Divisions, Instrument Society of America], Las Vegas, NV (33rd International Instrumentation Symposium, 738 W. Larigo Ave., Littleton, CO 80120)

11-15 ASA Spring Meeting, Indianapolis, IN

12-13 International Appliance Technical Conference, Columbus, OH

JUNE

8-10 AIAA 19th Fluid Dynamics, Plasma Dynamics and Laser Conference

8-10 Noise-Con 87, Pennsylvania State University (Conference Secretariat, NOISE-CON 87, The Graduate Program in Acoustics, Applied Science Building, University Park, PA 16802)

16-18 11th Annual Meeting [Vibration Institute], St. Louis, MO (Dr. Ronald L. Eshleman, Director, Vibration Institute, 55th and Holmes, Clarendon Hills, IL 60514 - (312) 654-2254)

29-2 AIAA/SAB/ASME/ASBE 23rd Joint Propulsion Conference, San Diego, CA

AUGUST

31-2 Twentieth Midwestern Mechanics Conference (20th MMC), Purdue University, West Lafayette, IN (Professors Hamilton and Soedel, School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907)

SEPTEMBER

27-30 Vibrations Conference and Other Technical Conferences, Boston, MA

NOVEMBER

15-19 ASME Winter Annual Meeting, New York, NY

16-20 ASA Fall Meeting, Miami, FL

**CALENDAR ACRONYM DEFINITIONS
AND ADDRESSES OF SOCIETY HEADQUARTERS**

AHS	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036	IMechE	Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1, UK
AIAA	American Institute of Aeronautics and Astronautics 1633 Broadway New York, NY 10019	IFTOMM	International Federation for Theory of Machines and Mechanisms U.S. Council for TMM c/o Univ. Mass., Dept. ME Amherst, MA 01002
ASA	Acoustical Society of America 335 E. 45th St. New York, NY 10017	INCE	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
ASCE	American Society of Civil Engineers United Engineering Center 345 E. 47th St. New York, NY 10017	ISA	Instrument Society of America 67 Alexander Dr. Research Triangle Pk., NC 27709
ASLE	American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	SAE	Society of Automotive Engineers 400 Commonwealth Dr. Warrendale, PA 15096
ASME	American Society of Mechanical Engineers United Engineering Center 345 E. 47th St. New York, NY 10017	SEM	Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis) 7 School Street Bethel, CT 06801
ASTM	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	SEE	Society of Environmental Engineers Owles Hall Buntingford, Hertz. SG9 9PL, England
ICF	International Congress on Fracture Tohoku University Sendai, Japan	SNAME	Society of Naval Architects and Marine Engineers 74 Trinity Pl. New York, NY 10006
IEEE	Institute of Electrical and Electronics Engineers United Engineering Center 345 E. 47th St. New York, NY 10017	SPE	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
IES	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	SVIC	Shock and Vibration Information Center Naval Research Laboratory Code 5804 Washington, D.C. 20375-5000

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the **Shock and Vibration Digest**. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress **important recent technology**. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in **Digest** articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the following example:

Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and practical applications that have been explored [3-7] indicate . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, issue number, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter -- A Survey," *Shock Vib. Dig.*, 2 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., *Aeroelasticity*, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).

Articles for the **Digest** will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the **Digest**. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 3000 to 4000 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tamulionis

Research Editor

Vibration Institute

101 W. 55th Street, Suite 206
Clarendon Hills, Illinois 60514

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, DC 20375-5000

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE \$300

FIRST CLASS MAIL
POSTAGE & FEES PAID
USN
PERMIT No G 9

THE SHOCK AND VIBRATION DIGEST

Volume 18, No. 12

December 1986

EDITORIAL

1 SVIC Notes
2 Editors Rattle Space

ARTICLES AND REVIEWS

3 Feature Article -- Mechanical Signature Analysis
M.S. Hundal

12 Literature Review

13 Fracture Analysis -- A Review
D. Brock

23 Book Reviews

CURRENT NEWS

25 Short Courses
28 Reviews of Meetings

ABSTRACTS FROM THE CURRENT LITERATURE ; and

32 Abstract Contents
33 Availability of Publications
Abstracted
34 Abstracts: 86-2369 to 86-2615
92 Periodicals Scanned
100 Abstract Categories

ANNUAL INDEXES

101 Feature Articles
102 Literature Review
103 Book Reviews
105 Author Index
138 Subject Index

CALENDAR